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AIR TRAFFIC SEPARATION STUDIES: AN ANNOTATED LISTING OF READING--ETC(U)
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Report No. FAA-EM-77-13

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AIR TRAFFIC SEPARATION STUDIES:

AN ANNOTATED LISTING OF READING MATERIALS

Paul W. Bradbury

JANUARY 1978

FINAL REPORT

Prepared for

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Office of Systems Engineering Management
Washington, D.C. 20591

NOTICE

The United States Government does not endorse products or manufacturers. Trade or manufacturer's names appear herein solely because they are considered essential to the object of this report.

METRIC CONVERSION FACTORS

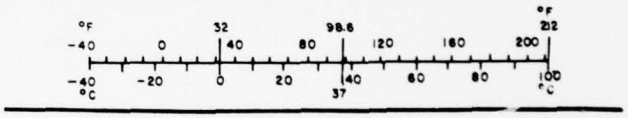
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-EM-77-13		

4. Title and Subtitle	5. Report Date
AIR TRAFFIC SEPARATION STUDIES: AN ANNOTATED LISTING OF READING MATERIALS ,	January 1978
	6. Performing Organization Code
7. Author(s) Paul W. Bradbury	8. Performing Organization Report No. FAA-NA-77-15
9. Performing Organization Name and Address Federal Aviation Administration National Aviation Facilities Experimental Center Atlantic City, New Jersey 08405	10. Work Unit No. (TRAIS) 11. Contract or Grant No. 012-102-230 13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Office of Systems Engineering Management Washington, D.C. 20591	Final rept. 1955 - 1976, 14. Sponsoring Agency Code

15. Supplementary Notes

118 p.

16. Abstract

This bibliographic compilation lists reading materials concerned with separation standards for the air traffic control system. Related subjects, such as collision risk analysis, navigational track-keeping error, descriptions of proposed navigational systems or aids, and cost/benefit trade-off studies of ATC system design, are included to some extent, but selectively rather than extensively or in depth.

Orientation of the materials selected for listing is largely, but not exclusively, toward oceanic enroute aspects of the international air traffic control systems. The North Atlantic system (NAT) is particularly evident; this follows naturally from the extensive study efforts organized under ICAO as the NAT Systems Planning Group and the special panel for "Review of the General Concept of Separation (RGSCP)." The style of presentation is tailored to facilitate rapid scan. Annotations are largely derivative from other sources, and the comments are descriptive rather than evaluatory. Comprehensiveness was sacrificed to selectivity to avoid unwieldness.

17. Key Words	18. Distribution Statement
Air Traffic Control ATC Systems Navigational Track-keeping Collision Risk Probability Mathematical Models	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	120	

240 550

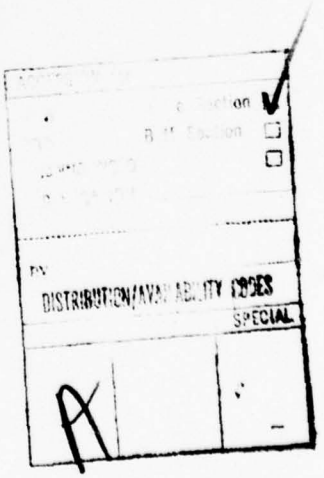
PREFACE

This bibliographic aid was prepared to assist those engaged in studies of separation standards in air traffic control. Other subjects, such as analysis of collision risk or of aircraft navigational accuracy (track-keeping), cost/benefit trade-offs related to aircraft delays and diversions, or descriptions of aircraft navigational systems, are included to the extent with which they bear upon separation standards.

Items are sequenced alphabetically by author. A minimum of cross-referencing is admitted. As an example, the complexity of the Autonetics Report, "Concept for a Satellite-Based Advanced Air Traffic Management System" (10 volumes, February 1974) warrants a corporation listing in addition to individual listing of selected volumes by author.

The style of listing is intended to encourage rapid scan and to facilitate excerpting by item (via duplicator machine and scissors, perhaps). The author's name and initials are not transposed, inasmuch as we are concerned for the reader, not for the file clerk. The bibliographic source data is trimmed to a minimum. Sufficient source data is provided to enable either subsequent look-up in a technical library or direct correspondence with the indicated source.

The annotations are descriptive rather than evaluatory. No annotation may occur where the title is sufficiently self-descriptive, or in numerous instances in which time limitations precluded direct examination. Many annotations are based on similar comments in prefatory material or in other sources. No claim of creative originality is made. Technical evaluation is minimal. Journalistic comment occurs where it may save the user some time. To aid the user, some annotations expand the identification of author, provide some background of document generation or application, or identify associated (or closely parallel) documents. In sum, both usefulness and facility of use were sought; consistency of librarianship was not an objective.



M. D. Abbott (RAE) July 1965
SOME REMARKS ON THE DISTRIBUTION OF AIRCRAFT TRACK-KEEPING ERRORS

Journal of the Institute of Navigation (U.K.), London, England; Vol. 18, No. 3.

In the January 1965 Journal (Vol. 18, No. 1, "Is the Gaussian Distribution Normal?"), E. W. Anderson notes that the distribution of large navigational errors is frequently non-gaussian. He raises the point whether this can be accounted for by the generation of such errors in succession rather than simultaneously. This note describes a digital simulation which represents a flight over the North Atlantic that uses a simplified navigational procedure having such a successive generation of error. The output from the simulation consists of histograms of the track-keeping errors at various longitudinal positions, which can be compared with those obtained from gaussian and exponential distributions.

J. D. Ackerman April 1965
PROBLEMS INVOLVED IN DETERMINING NAVIGATION SYSTEM ACCURACY

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE, (Miami), working paper WP-83.

Wing Commander Ackerman is associated with the U.K. Aeroplane and Armament Experimental Establishment, Boscombe Down. The Experimental Establishment also generated other working papers concerning navigation for IATA Sixteenth: WP-71 (Polar Path Compass) by E. T. Wood, WP-73 (Automatic Dead Reckoning with Loran-A and Doppler) by P. M. Hinchcliffe, and WP-79 (AN/AVN-1 Astro Navigational Set) by the Experimental Establishment.

AGARD CP-56 May 1969
MEASUREMENT OF AIRCREW PERFORMANCE: THE FLIGHT DECK WORKLOAD AND ITS RELATION TO PILOT PERFORMANCE

NATO Advisory Group for Aerospace Research and Development, Neuilly-sur-Seine, France; AGARD Conference Proceedings No. 56.

AGARD CP-105 June 1972
AIR TRAFFIC CONTROL SYSTEMS

NATO Advisory Group for Aerospace Research and Development, Neuilly-sur-Seine, France; Proceedings of the First AGARD Symposium on ATC (Edinburgh).

An excellent update of information on specific projects. However, recognizing a need for "a general survey of modern concepts and techniques used in or

applicable to the control of air traffic," AGARD subsequently issued (July 1975) AGARDograph No. 209: A Survey of Modern Air Traffic Control (AGARD-AG-209, Vols. I and II).

Papers related to aircraft separation or collision risk include the following:

Tyler, Stepner, Sorensen (SCI): "An ATC/Surveillance Modeling Approach for Specifying Lane Separation Standards;"

"Discussion on Session II: Area and Enroute Navigation;"

J. L. Parsons (RCA): "SECANT--A Solution to the Problem of Mid-Air Collisions;" and

V. D. Hopkin (RAF, Farnborough): "Human Factors Problems in Conflict Detection and Resolution."

AGARD CP-146 April 1974
SIMULATION AND STUDY OF HIGH WORKLOAD OPERATIONS

NATO Advisory Group for Aerospace Research and Development, Neuilly-sur-Seine, France; AGARD Conference Proceedings No. 146.

AGARD AG-209 Vols. I and II July 1975
A SURVEY OF MODERN AIR TRAFFIC CONTROL

NATO Advisory Group for Aerospace Research and Development, Neuilly-sur-Seine, France; AGARDograph No. 209.

Technical papers are organized into five categories: (Volume I) General Organization of ATC, Human Factors in ATC, Automation of Control Procedures; (Volume II) Technical Aids to Air Traffic Control, Operational Air Traffic Control Systems. AGARD's Guidance and Control Panel published this selection from 100 papers submitted for the first AGARD symposium on air traffic control (June 1972 in Edinburgh) in order to fill the need for a general survey of modern concepts and techniques applicable to air traffic control. The proceedings of the symposium were previously published in AGARDograph CP-105.

AGARD CP-188 February 1976
PLANS AND DEVELOPMENTS FOR AIR TRAFFIC SYSTEMS

NATO Advisory Group for Aerospace Research and Development, Neuilly-sur-Seine, France; AGARD Conference Proceedings No. 188.

Papers presented at the 20th Symposium of the AGARD Guidance and Control Panel, Cambridge, Mass., May 20-23, 1975, of which the following may be of some interest:

Editors: Dr. A. Benoit, EUROCONTROL, Belgium, and David R. Israel, FAA.
K. Watling and R. C. Rawlings, U.K.: Studies of Automatic Navigation Systems to Improve Utilization of Controlled Airspace;
V. W. Attwooll: The Optimization of Traffic Flow Around a Network;
Benoit, Storey, and Swierstra: The Introduction of Accurate Aircraft Trajectory Predictions in Air Traffic Control;
Ball, Lloyd, and Ord: Interactive Conflict Resolution in Air Traffic Control;
Perie, Horowitz, McFarland, Beusch, and Senne: Intermittant Positive Control;
Ljubimko Milosevic: Integrated Navigation System Multifunction (in French as Article 18; in English as Article 19);
K. J. Brauser (Messerschmitt): Measurements of the Control Capacity of ATC Systems; and
H. Gent (Royal Radar Est.): A Measuring Rod for ATC Systems - The Index of Orderliness.

Air Canada April 1965
CAUSES OF ERRORS IN TRACK MAINTENANCE

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE, (Miami), working paper WP-14.

Air Traffic Conference of America June 1, 1977
OFFICIAL AIRLINE GUIDE: NORTH AMERICAN EDITION

The Reuben H. Donnelley Corporation, Oak Brook, Illinois (publishers); published twice monthly.

This standard reference periodical is devoted to listings of airline schedules paired by cities of arrival/departure, with supportive information such as ground transportation, baggage allowances and rates, fares information, air taxi, air cargo, mileages, routes, maps, and various types of codes used in the business. Of interest related to operational air traffic system studies, the contents offer clarification and provide data inputs for traffic sample generation. The OAG North American Edition is published twice monthly; the OAG Worldwide Edition is published monthly.

B. Alexander March 1970
AIRCRAFT DENSITY AND MIDAIR COLLISION

Institute of Electrical and Electronics Engineers, Inc., New York, New York; proceedings of IEEE, Vol. 58, No. 3, pages 377-381.

The frequency of near midair collisions under visual flight rules as a function of aircraft density is derived from a model which correlates closely with recent experience. Examples are given which indicate the degree of air traffic control needed for safe separation at various levels of aircraft density for both unordered and ordered flight. It is argued that loose forms of ATC, such

as intermittent positive control can be used safely to prevent collisions while preserving most of the freedom of VFR flight at densities as high as those predicted for peak hours in the Los Angeles Basin in 1955.

E. W. Anderson 1965
IS THE GAUSSIAN DISTRIBUTION NORMAL?

Journal of the Institute of Navigation (U.K.), London, England; Vol. 18, No. 1.

The distribution of large navigational errors is frequently observed to be non-gaussian in character. The author raises the point whether this can be accounted for by the generation of such errors in succession rather than simultaneously. The successive generation of navigation errors arises through the error incurred on a particular leg being distributed about a mean which is dependent on the error up to the end of the previous leg. He arrives at the conclusions: (1) that the exponential distribution may apply where errors are generated successively, and (2) the exponential distribution appears to apply more widely in navigation than does the gaussian except for small errors. See also M. D. Abbott: Some Remarks on the Distribution of Track-Keeping Errors.

E. W. Anderson Spring 1971
AIR NAVIGATION TECHNIQUES

NAVIGATION: Journal of the Institute of Navigation (U.S.), Washington, D.C.; Vol. 18, No. 1.

Wing Commander Anderson (RAF) was associated with Smith's Industries, Ltd., when he was invited to contribute this article for the 25th anniversary of NAVIGATION. Non-technical journalistic review. Recapitulates very briefly the history of flight navigation from the introduction of radio techniques to the introduction of satellites and use of the airborne computer. Touches on introduction of ION, RTCA, ICAN, PICAO, ICAO, ARINC, VHF, VOR, DME, LORAN, ADF, and many more. An aid to the uninitiated contractor or student researcher.

E. W. Anderson and D. M. Ellis October 1971
ERROR DISTRIBUTIONS IN NAVIGATION

Journal of Navigation (U.K.), London, England; Vol. 24, No. 4.

Emphasis is placed on the distinction between distributions involving identical items and those involving a number of items which, although nominally the same, are in fact diverse. It is shown how the apparent variation of results that arise in practice, may be unified into a simple inclusive pattern. It is pointed out that the convex distribution (of which the Gaussian appears to be a limiting example) arises when only one object is involved or when a number of objects are so similar that they may be regarded as manifestations of the same object.

Roy E. Anderson (General Electric Co.) January 1966
A CONCEPT FOR NAVIGATION AND COMMUNICATION USING SATELLITES

Journal of the Institute of Navigation (U.K.), London, England; Vol. 19, No. 1.

R. G. Anderson and P. G. Reich October 1965
SEPARATION STANDARDS IN THE LONG-RANGE AIR TRAFFIC CONTROL REGION WITH SPECIAL REFERENCE TO VERTICAL SEPARATION

IFALPA Symposium; Royal Aircraft Establishment Technical Report RAE R2785060.

R. G. Anderson November 1965
RESULTS OF THE 1965 FLIGHT-DECK DATA COLLECTION ON HEIGHT-KEEPING OVER THE NORTH ATLANTIC

Royal Aircraft Establishment, Farnborough, England; RAE Technical Report 65268.

R. G. Anderson December 1965
SURVEY OF THE ERRORS OF PRESSURE-MEASURING INSTRUMENTS IN RELATION TO AIR TRAFFIC SEPARATION STANDARDS

Royal Aircraft Establishment, Farnborough, England; RAE Technical Report 65262.

R. G. Anderson and P. G. Reich May 1966
SPECIFYING THE CALIBRATION OF STATIC PRESSURE SYSTEMS FOR THE SAFE USE OF 1000-FOOT VERTICAL SEPARATION STANDARD IN NORTH ATLANTIC JET TRAFFIC

Royal Aircraft Establishment, Farnborough, England; RAE Technical Report 66156.

R. G. Anderson September 1966
A REVIEW OF THE EVIDENCE ON THE TRACK-KEEPING PERFORMANCE OF JETS IN THE NORTH ATLANTIC REGION IN THE PERIOD 1965-1966

Royal Aircraft Establishment, Farnborough, England; RAE Technical Report 66295.

Results are given for four data collections in 1965/66 which give evidence on the navigation accuracy in the North Atlantic Region. These are compared with earlier measurements and explanations are offered for some of the discrepancies between the data from the various sources.

J. W. Andrews and G. Prado (Lincoln Laboratories) November 1972
THE INFLUENCE OF SURVEILLANCE SYSTEM PARAMETERS ON AUTOMATED CONFLICT DETECTION AND RESOLUTION

Lincoln Laboratory, Lexington, Mass.; Technical Report No. FAA-RD-72-100.

ARCON Corporation July 1961
AIR TRAFFIC CONTROL THEORY AND DESIGN

ARCON Corporation, Lexington, Mass.; ARCON No. 1-61; prepared for The Mitre Corporation under subcontract No. 49-FAA/BRD-157.

A major--and early--effort to design a collision-free, semi-automatic operational Air Traffic Control system. Describes and discusses basic approach, collision geometry, "control geometry," conflict detection, collision avoidance, conformance checking, errors of navigation, tracking, and prediction; and presents statistical models applicable to air traffic situations and systems. Develops relationships between the system operating parameters and the performance measures. Begins with a discussion of simple mathematical models of collision geometry, and presents in detail models of air traffic statistics and system errors. Presents the design, the analysis, and the optimization of a control system configuration which models a "SATIN"type control function.

ARCON Corporation March 1962
A DISCUSSION OF THE NORTH ATLANTIC AIR TRAFFIC SYSTEM

ARCON Corporation, Lexington, Mass.; Memorandum Report No. M-62-1.

ARCON Corporation December 1962
SYSTEM ANALYSIS OF THE NORTH ATLANTIC AIR TRAFFIC COMPLEX

ARCON Corporation, Lexington, Mass.; ARCON Technical Report No. R62-3 (December 1962); 283 pp., 62 illus., 7 tables; Contract FAA/BRD-334.

A detailed analysis of the North Atlantic Air Traffic Control System, which stresses the application and interpretation of mathematical models (Sections I-IX). Describes present system (Section III). Discusses potential modifications in separation standards, navigation, control procedures, communications, aircraft, and weather forecasting. Develops the relationships between separation standards and other aspects of the Air Traffic System; compares alternate system configurations (Section V). Detailed mathematical developments are given in several appendices: Statistical Model of Wind Behavior, Effect of Winds on Longitudinal Separation, Analysis of Fix Errors, Lateral Track-Keeping Errors, System Capacity, Analysis of Minimal Time Path. Twenty-three-item bibliography is of interest.

ARCON Corporation September 1964
ANALYSIS OF ORGANIZED ROUTE SYSTEMS IN THE NORTH ATLANTIC

ARCON Corporation, Lexington, Mass.; Final Report to FAA/SRDS under Contract FA-WA-4620.

The operational and economic consequences of adopting organized route procedures in the North Atlantic Air Traffic Control System are examined. A technique for the formulation of traffic forecasts is presented, and their significance to the system designer is discussed. Detailed mathematical treatments and descriptions of digital computer simulations which were applied in this effort are described in the appendices.

ARCON Corporation May 1968
STUDY OF FUTURE OCEANIC AVIATION SUPPORT SYSTEMS

ARCON Corporation, Wakefield, Mass.; Final Report to FAA, SRDS, under Contract No. FA67WA-1680 (Project 197-622-02R).

F. J. Arnold (Australia) October 1974
A METHOD OF PLANNING PARALLEL AIR ROUTES IN A NON-RADAR ENVIRONMENT

ICAO Review of the General Concept of Separation Panel, Working Group "C"; Ninth Meeting, London, October 23-25, 1974; working paper RGCSP-C-WP/59.

F. J. Arnold (Australia) October 1974
VARIATION FROM NOMINAL CRUISING LEVEL DUE TO FLIGHT TECHNICAL ERROR

ICAO Review of the General Concept of Separation Panel, Working Group "C"; Ninth Meeting, London, October 23-25, 1974; working paper RGCSP-C-WP/62.

F. J. Arnold (Australia) October 1974
ALTIMETER RELIABILITY

ICAO Review of the General Concept of Separation Panel, Working Group "C"; Ninth Meeting, London, October 23-25, 1974; working paper RGCSP-C-WP/67.

ASTIA January 1962
AIR TRAFFIC CONTROL SYSTEMS (AN ASTIA REPORT BIBLIOGRAPHY)

Armed Services Technical Information Agency, Arlington, Va.

ATA (Air Transport Association) March 1969
AIRBORNE COLLISION AVOIDANCE SYSTEM

Air Transport Association of America, Washington, D.C.; ATA Air Navigation and Traffic Control Division document, No. ANTC-117, Revision 8.

This document of the airline industry association provides the statement of ATA policy and requirements, and a technical description of the CAS (Collision Avoidance System). In respect to each of these, the document comments on air traffic separation standards, although not extensively. Revision 7 (Aug. 1968) was attached to AEEC Letter 69-2-41 (Aug. 1969). Subsequent revisions 9 and 10 appeared in July 1970 and Sept. 1971, respectively.

ATA (Air Transport Association) June 13, 1969
AN AIRLINE VIEW OF "THE MEANING OF THE STATISTICAL APPROACH TO SAFETY"

Air Transport Association of America, Washington, D.C.; by Aeronautical Radio Inc., ARINC Autopilot Newsletter, No. 107.

V. W. Attwooll (RAE) October 1964
THE OPTIMUM DESIGN OF A PARALLEL ROUTE STRUCTURE FOR AIR TRAFFIC FROM LONDON TO NEW YORK FOR VARIOUS SEPARATION STANDARDS

Royal Aircraft Establishment, Farnborough, England; RAE Technical Report 64034.

Defines a model of routes which are parallel to the minimum-time path between London and New York. Describes a simulation made to assess the traffic distribution and the cost-penalties for various separation standards and traffic densities. Treats subsonic aircraft and supersonic transports separately, and discusses the probable differences between them.

See also V. W. Attwooll's papers (under titles which differ very slightly), published April 1965 as Working Paper WP-76 in proceedings of the IATA 16th Technical Conference (Miami, April 1965), and October 1965 in the Journal of the Institute of Navigation (U.K.), Vol. 18, No. 4.

V. W. Attwooll (RAE) April 1965
OPTIMUM DESIGN OF PARALLEL ROUTE STRUCTURES FOR NORTH ATLANTIC AIR TRAFFIC

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE, (Miami); working paper WP-76.

Sets up a model of North Atlantic airspace in which there are sets of paths at various heights for air routes, each path being parallel to the minimum-time path from London to New York. Aircraft entering the system are allocated

to the "best available path" using as criteria least cost or least fuel. A computer simulation is then made to assess traffic distribution and the cost-penalities in time, fuel, or operating costs. The assessment considers several sets of separation standards and traffic densities. Part I deals with subsonic traffic and considers the impact of reductions in separation standards on costs. Part II deals with supersonic traffic, considering sonic boom and differences from subsonic traffic.

See also V. W. Attwooll's papers (under titles which differ very slightly), published in October 1964 as RAE Technical Report No. RAE-64034, and in October 1965, in Journal of the Institute of Navigation (U.K.), Vol. 18, No. 4. During 1966, V. W. Attwooll published several papers on parallel route structures as well as several on costing aircraft route deviations imposed by ATC.

V. W. Attwooll (RAE) October 1965
OPTIMUM DESIGN FOR PARALLEL ROUTES IN THE NORTH ATLANTIC

Journal of the Institute of Navigation (U.K.), London, England; Vol. 18, No. 4.

Routes are constructed parallel to the minimum-time path from London to New York. A computer simulation is then made to assess cost-penalties in time and fuel imposed by allocation of initiating flights to the "best available path" and by the application of various traffic densities. Supersonic and subsonic air traffic are treated separately, and the probable differences are discussed.

See also V. W. Attwooll's papers (under titles which differ very slightly), published October 1964 as RAE Technical Report No. RAE-64034, and in April 1965 as Working Paper WP-76 in Proceedings of the IATA 16th Technical Conference (Miami, April 1965).

V. W. Attwooll (RAE) January 1966
COSTING AIR TRAFFIC CONTROL DEVIATIONS

Journal of the Institute of Navigation (U.K.), London, England; Vol. 19, No. 1.

Discusses methods of costing the effects of air traffic control deviations imposed on aircraft flight operations and relates such costs to the size of separation standards. Discusses supersonic transport operations as well as subsonic transport. See also Attwooll's RAE Technical Report (RAE TR66148) of May 1966, under similar title.

V. W. Attwooll (RAE) February 1966
SOME COST ESTIMATES OF THE TRAFFIC SYSTEM FOR THE CONCORDE ON THE NORTH ATLANTIC

Royal Aircraft Establishment, Farnborough, England; RAE Technical Memorandum TM-Math-70.

V. W. Attwooll (RAE) April 1966
THE PARALLEL-ROUTE SYSTEM FOR NORTH ATLANTIC SUBSONIC JET TRAFFIC

Journal of the Institute of Navigation (U.K.), London, England; Vol. 19, No. 2.

Includes relation of separation standards to operating costs. See also his paper for Supersonic Jet Traffic in Journal of the Institute of Navigation (U.K.), Vol. 19, No. 3, July 1966, as well as earlier papers on optimum design of parallel route structures in RAE TR-64034 (October 1964), IATA 16th Technical Conference (April 1965), and Journal of the Institute of Navigation (U.K.), Vol. 18, No. 4 (October 1975).

V. W. Attwooll (RAE) May 1966
METHODS OF COSTING DEVIATIONS FROM OPTIMUM CRUISE FLIGHT PATH--WITH EXAMPLES OF THE LONDON-NEW YORK ROUTES

Royal Aircraft Establishment, Farnborough, England; RAE Technical Report 66148.

See also his article under similar title in Journal of the Institute of Navigation (U.K.), London, Vol. 19, No. 1, January 1966.

V. W. Attwooll (RAE) July 1966
PARALLEL ROUTE SYSTEMS FOR SUPERSONIC TRAFFIC

Journal of the Institute of Navigation (U.K.), London, England; Vol. 19, No. 3.

This is the third article of a series of three describing the methods developed at the Royal Aircraft Establishment for costing the effect of air traffic control deviations in long range systems. The first two discussed the general principles of costing and their application to the current and future systems for subsonic aircraft over the North Atlantic. This paper considers systems for the SST.

V. W. Attwooll (RAE) February 1967
THE EFFECTS OF TRAILING VORTICES ON THE SAFE CAPACITY OF AIR ROUTES AND AIRPORTS

Royal Aircraft Establishment, Farnborough, England; RAE Technical Memorandum TM-Math-6702.

V. W. Attwooll (RAE) July 1968
STUDIES OF THE DESIGN OF A TRANSATLANTIC ROUTE STRUCTURE FOR SUPERSONIC TRANSPORTS

Royal Aircraft Establishment, Farnborough, England; RAE Technical Report 68183.

Presents the results of fast-time simulation studies of possible systems for Concorde and other SST traffic over the North Atlantic. For a given layout of the track system and level of traffic flow, the simulations give the incidence of deviations and delays, from which is estimated the required increase in fuel reserve and extra cost penalty. Results show the advantage of a single-layer track system with aircraft free to cruise-climb, the large effect of possible restrictions to avoid sonic-bang over land, the effect of variations in separation minima, and the advantage of an ATC system using entry delay on a tactical basis to facilitate maximum use of the best tracks in the system.

V. W. Attwooll (RAE) Summer 1968
SEPARATION CRITERIA FOR SUPERSONIC TRANSPORTS AND OTHER ASPECTS OF TRAFFIC CONTROL

NAVIGATION: Journal of the Institute of Navigation (U.S.), Washington, D.C.; Vol. 15, No. 2.

Discusses studies of the traffic system for the supersonic transport at the RAE, the design for the oceanic traffic system having regard to the performance characteristics of the atmosphere at the heights to be flown and to possible restriction of supersonic flight overland. Cost effectiveness studies give desirable values for oceanic separation minima.

V. W. Attwooll December 10, 1970
THE EQUATIONS OF AIR COLLISION

New Scientist, Vol. 48.

Discussion of approaches to meet the air traffic control requirements of the future, giving attention to an analysis using collision risk equations. The chances of collision between two aircraft flying in a roughly parallel direction, but deviating from their intended path because of various kinds of error are investigated making use of equations which give the expected number of collisions for each mode of collision. The application of this analysis to the North Atlantic traffic system and to Britain's airspace is discussed. It is pointed out that an air traffic system, in which all aircraft follow the most direct course, is not feasible, at present, because of the complexity of the work which the computer would have to perform. The merits of an airborne collision avoidance system developed in the United States are critically examined.

V. W. Attwooll (RAE) April 1974
AIRCRAFT CHARACTERISTICS AND AIR TRAFFIC SYSTEMS

Journal of Navigation (U.K.), London, England; Vol. 27, No. 2; paper read at the Institute of Navigation meeting, London, November 28, 1973.

Discusses the impact of expected changes in aircraft design which will be "tailored to optimize the traffic system" rather than for economically efficient operation. See in particular, the treatment of "Vertical Crossover" for separation implications.

V. W. Attwooll (RAE) February 1976
THE OPTIMISATION OF TRAFFIC FLOW AROUND A NETWORK

NATO Advisory Group for Aerospace Research and Development, Neuilly-sur-Seine, France; Paper No. 15 in AGARD Conference Proceedings No. 188, 20th Symposium of the AGARD Guidance and Control Panel, Cambridge, Mass.; May 20-23, 1975.

Considers the use of flow control on routes subject to saturation. Using examples of traffic conditions at the England/France boundary, suggests the use of "computer optimisation techniques as a means of assessing and planning an optimum traffic flow rate on a given route." From this basis, proceeds to determination of optimum distribution of flow rates planned along various routes of a network; hence the rescheduling desired at each of the "traffic-generating airports." Methodology employs some basic equations. 5 pp.; 1 graphic.

Autonetics June 1972
FOURTH GENERATION AIR TRAFFIC CONTROL STUDY: SUMMARY (VOLUME 1)

Autonetics Avionics and Sensors Division, North American Rockwell Corporation, Anaheim, CA 92803. Final Technical Report DOT-TSC-304-1.

Extends the work of the ATCAC (ATC Advisory Committee of DOT 1969) in defining a Fourth Generation ATC System. Autonetics conducted a 10-month study in three phases. In Phase I, goals and demands for 1975-1990 were evaluated, candidate systems were compared and discarded or combined. Two concepts were chosen for further analysis. In Phase II, performance measurements were identified, and the two selected concepts were evaluated and compared against the UG3rd ATC System. In Phase III, a hybrid of the best features of the Phase II concepts was evaluated and compared against the Phase II concepts and the UG3rd. Operational phase-in criteria and a transition plan were developed.

The report is organized into a summary volume and three volumes of appendixes. Volume II, Appendix A: Demand, Requirements, Operational Concept Analysis; Volume III, Appendixes B, C, D: Candidate System Concepts, Implementation Plan, Cost Analysis; Volume IV, Appendix E: Technology Pertinent to the Fourth Generation ATC System. See also Report TSC-306-1, by Boeing Corp.

As defined in the extensive "Glossary," a control concept describes how planning, navigation, and intervention will be used to accomplish safe and efficient flight; must address various user classes, airspace elements, cross-track and along-track flight dimensions..., and considers procedures which clearly define legal responsibility for safety in flight. The essential ingredient of a control concept may therefor be considered to be separation standards. This report is considered germane, although specific attention to collision risk estimation is minimal.

Autonetics February 1974
CONCEPT FOR A SATELLITE-BASED ADVANCED AIR TRAFFIC MANAGEMENT SYSTEM: VOLS. I-X

Rockwell International Corp., Autonetics Division, Anaheim, California; Technical Report DOT-TSC-OST-73-29, for Transportation Systems Center, Cambridge, Mass.

Reports the results of studies directed toward definition of "SAATMS-- a Satellite-Based Advanced Air Traffic Management System." Presented in ten volumes; the titles herewith adequately indicate their separate contents. Volume I summarizes study findings in tabular form with a minimum of prose expansion. In Volume IX, Autonetics presents the models used to analyze basic features and to represent the relationships between system output measures and system inputs or variables of system structure and system state. Volume IX includes some analysis of models related to aircraft separation and collision risk. Volume X considers terminal spacing of 1.5 nautical miles, and, in the enroute sector, blunders of less than 22 feet/sec^2 using aircraft separations of 5, 7, and 10 nautical miles. Models of separation standards are presented on page 10 ff.

H. T. Freedman, et al. DOT-TSC-OST-73-29, I
VOLUME I: SUMMARY

R. G. Loeliger, et al. DOT-TSC-OST-73-29, II
VOLUME II: SYSTEM FUNCTIONAL DESCRIPTION AND SYSTEM SPECIFICATION

R. G. Loeliger, et al. DOT-TSC-OST-73-29, III
VOLUME III: SUBSYSTEM FUNCTIONAL DESCRIPTION

C. S. Hoffman, et al. DOT-TSC-OST-73-29, IV
VOLUME IV: OPERATIONAL DESCRIPTION AND QUALITATIVE ASSESSMENT

J. C. Elsey, et al. DOT-TSC-OST-73-29, V
VOLUME V: SYSTEM PERFORMANCE

H. T. Freedman, et al DOT-TSC-OST-73-29, VI
VOLUME VI: DEVELOPMENT AND TRANSITION PLANS

T. Felisky and H. T. Freedman DOT-TSC-OST-73-29, VII
VOLUME VII: SYSTEM COST

C. V. Hamilton, et al. DOT-TSC-OST-73-29, VIII
VOLUME VIII: OPERATIONAL LOGIC FLOW DIAGRAMS

C. Chen, R. G. Loeliger, F. S. Nakamoto, et al. DOT-TSC-OST-73-29, IX
VOLUME IX: SYSTEM AND SUBSYSTEM PERFORMANCE MODELS

J. B. King, C. I. Cheng, R. P. Utsumi DOT-TSC-OST-73-29, X
VOLUME X: SUBSYSTEM PERFORMANCE REQUIREMENTS

A. E. Barnsby December 16, 1968
AIRSPACE MODEL DESCRIPTION

The MITRE Corporation, McLean, Virginia.

ERC Internal Note No. 68-AS-4, under FAA-MITRE Contract NAS-12-2039, during development of the FAA automated system concept then labelled "National Airspace System (NAS)."

A. E. Barnsby and J. A. Keenan March 21, 1969
ANNOTATED BIBLIOGRAPHY OF DOCUMENTS RELATED TO TERMINAL AREA MODELING

The MITRE Corporation, McLean, Virginia; MITRE Technical Report MTR 4070.

H. G. Baudry 1973
MODEL TO EVALUATE THE RISK OF COLLISION AND THE FREQUENCY OF INTERVENTION IN A DUAL TRACK SYSTEM WITH SURVEILLANCE

ICAO Review of the General Concept of Separation Panel, Working Group "C"; working paper RGCS-C/WP-unnumbered.

H. G. Baudry 1973
LONGITUDINAL SEPARATION FOR SAME DIRECTION TRAFFIC ON SAME ROUTE

ICAO Review of the General Concept of Separation Panel, Working Group "C"; working paper RGCS-C/WP-unnumbered.

H. G. Baudry October 1974
EXPERIMENTAL EVALUATION OF THE AUTOMATIC SURVEILLANCE OF LATERAL DEVIATION

ICAO Review of the General Concept of Separation Panel, Working Group "C"; Ninth Meeting, London, October 23-25, 1974; working paper RGCS-C/WP-57.

H. G. Baudry October 1974
CALCULATION OF THE SEPARATION BETWEEN PARALLEL AIRWAYS UNDER RADAR SURVEILLANCE

ICAO Review of the General Concept of Separation Panel, Working Group "C"; working paper RGCS-C/WP-58.

Juan F. Bellantoni (N.Y. University) October 1971
THE CALCULATION OF AIRCRAFT COLLISION PROBABILITIES

Department of Transportation, Transportation Systems Center, Cambridge, Mass.; Report No. DOT-TSC-FAA-71-27.

The basic limitation on air traffic compresssion is the increased risk of collision due to reduced separations. It is desirable to extend the method of collision probability calculation (which has been limited to parallel, straight-line flight paths) to arbitrary flight paths and vehicle shapes. The general formula is specialized to the cases of large relative velocity, non-zero relative velocity, zero relative velocity, and spherical collision surface. The formulas are applied to independent curved landing approaches to parallel runways.

The formulas derived allow the calculation of collision probability between two aircraft flying arbitrary curvilinear paths. The analyses result in a general integral expression for the collision probability; simpler integral formulas are derived for the cases of a large relative velocity and a spherical collision surface.

J. W. Bennett and H. Gent January 1975
THE APPLICATION OF AN INDEX OF ORDERLINESS TO A COLLISION AVOIDANCE SYSTEM

Royal Radar Establishment, RRE Memorandum 2913.

Defines "Index of Orderliness" as a general purpose, quantitative measure of ATC system performance; attributes its adaptation to such use to A. G. Halverson (FAA/NAFEC). Describes its application to a CAS (Collision Avoidance System) simulation study, in which the Index was used to analyse the flow of traffic down intersecting airlanes. Output consists of an Index of Orderliness time-curve. Twelve pages, plus eight data plots.

See also H. Gent "A Measuring Rod for ATC Systems: The Index of Orderliness" in AGARD Conference Proceedings, CP-188 (February 1976). Also see FAA Technical Note (FAA/NAFEC, August 1971) "Index of Orderliness: Proposed Measure of ATC System Performance."

The overall aim is to demonstrate that an Index of Orderliness can be applied to an ATC system and used to obtain meaningful results.

A. Benoit, J. Storey, and S. Swierska (*EUROCONTROL*) February 1976
THE INTRODUCTION OF ACCURATE AIRCRAFT TRAJECTORY PREDICTIONS IN AIR TRAFFIC CONTROL

NATO Advisory Group for Aerospace Research & Development, Neuilly-sur-Seine, France; AGARD-CP-188 (Plans and Developments for Air Traffic Systems); paper presented at the 20th Symposium of the Guidance and Control Panel of NATO/AGARD, held May 20-23, 1975, Cambridge, Mass., at the Transportation Systems Center.

Proposes a family of methods for predicting aircraft trajectory based on limited history from radar observations. Describes the approach followed thus far; presents plans for future development. Describes the mathematical methods and algorithms, defines input data requirements. Summarizes results thus far obtained in trajectory prediction. 28 pp., 16 graphics; useful list of references.

D. I. Benton December 1961
SAFETY AND SEPARATION STANDARDS: SATIN DESIGN NOTE NO. 516

The MITRE Corporation, McLean, Virgina; MITRE working paper W-4576.

John F. Berglund (Texas Instruments, Inc.) December 1969
RADAR APPLICATIONS TO POST-L(*) ARC SURVEILLANCE MONITORING

Department of Transportation, Washington, D.C.; published as Appendix E-3 of the "Report of the DOT ATC Advisory Committee," Volume 2.

Packs into nine pages a thorough review of radar applications in the current ATC system and briefly discusses the constraints. Comments briefly on aspects of radar predicted or proposed for the post-1980 period. Straightforward, comprehensible, and informative.

H. C. Black 1971
OBJECTIVES AND STANDARDS FOR AIR SAFETY

Aeronautical Journal, Vol. 75, p.551.

D. A. Blake March 1971
MATHEMATICAL MODEL FOR ESTIMATING COLLISION RISKS ASSOCIATED WITH PROCEDURAL LONGITUDINAL SEPARATION STANDARDS

ICAO Review of the General Concept of Separation Panel, Working Group "C"; working paper RGCS-C/WP-unnumbered.

D. A. Blake 1974
PROPOSALS FOR STUDY, DATA COLLECTION, AND METHODOLOGY DEVELOPMENT RELATED TO THE DEFINED INITIAL TASKS OF THE WORKING GROUP

ICAO Review of the General Concept of Separation Panel, Working Group "C"; working paperR RSP-C/WP-10.

Howard A. Blank and Per A. Kullstam June 1971
A SURVEILLANCE MODEL FOR AIR TRAFFIC CONTROL BASED ON DIFFUSION THEORY

Institute of Navigation (U.S.), Washington, D.C.; in Proceedings of the 17th ION Meeting.

This report by Computer Sciences Corporation (Falls Church, Va.) was presented in Pasadena at the 17th Meeting of the ION. It advances a theory of the stochastic motion of aircraft in a controlled environment, based on classical diffusion processes.

The report develops the proposed surveillance model to the point where validation with empirical data is indicated. To advance the model, the report discusses only the lateral motion of an aircraft from the center line of the NOZ to the ILB, and the corresponding intervention statistics of the ATC system. The authors comment on basic papers by P. G. Reich and on subsequent attempts to model outliers of the distribution of lateral deviations from course and to define the "tails" of the distribution.

Terms are defined which have been somewhat accepted into the technical jargon of ATC systems study: NOZ (Normal Operating Zone), IZ (Intervention Zone), DZ (Detection Zone), OLB (Outer Lane Boundary), ILB (Inner Lane Boundary), RMZ (Recovery Maneuver Zone), and NTZ (No Transgression Zone).

The report is neatly outlined in six pages of Abstract and Introduction.

A. Blumstein July 1959
AIRCRAFT COLLISION PROBABILITIES ALONG A VERTICAL LINE

Cornell Aeronautical Laboratory (C.A.L.).

BOAC October 1965
FACTORS AFFECTING NAVIGATION OF THE S.S.T.

Journal of the Institute of Navigation (U.K.), London, England; Volume 18, No. 4.

British Overseas Airways Corporation in this paper comments on the need for precise navigation for supersonic transports, and points out the significance of the vertical dimension in air traffic control separation and aircraft operation. This paper was developed by the Operations, Engineering and Research Section of BOAC; and it may be accepted as an accurate, although informal, expression of the viewpoints and opinions of the aircraft operator.

Boeing January 1964
STATE-OF-THE-ART SURVEY FOR MINIMUM APPROACH, LANDING, AND TAKE-OFF INTERVALS AS DICTATED BY WAKES, VORTICES, AND WEATHER PHENOMENA

The Boeing Company, Renton, Washington; Technical Report No. FAA-RD-64-4.

The general argument--which concerns the influence on aircraft spacing intervals imposed by weather or aircraft wakes--relates to subject of interest.

Boeing May 1964
ANALYTICAL DETERMINATION OF THE VELOCITY FIELDS IN THE WAKES OF SPECIFIED AIRCRAFT

The Boeing Company, Renton, Washington; Technical Report No. FAA-RD-64-55.

The most recently investigated risk in aircraft-to-aircraft relationships is that generated from aircraft wakes. This report describes the nature and force of aircraft wakes and how these characteristics may be determined analytically. Such information comprises part of the input for the determination of aircraft separation standards.

Aircraft separation standards have recently been revised to reflect the conclusions from such studies. See also Aircraft Wake Vortices studies by Leo Garodz, et al. (FAA-NAFEC) circa 1970 and later.

Boeing April 1972

STUDY AND CONCEPT FORMULATION OF A FOURTH GENERATION AIR TRAFFIC CONTROL SYSTEM. VOLUME II: TECHNOLOGICAL ALTERNATIVES

> The Boeing Company, Renton, Washington; under contract for Department of Transportation, Transportation Systems Center, Cambridge, Mass.; Technical Report No. DOT-TSC-306-I.

In a 5-volume series, Boeing reports a study to aid selection of the most promising candidate systems (and their subsystem components) for a "Fourth Generation ATC System" (1995 and beyond).

The sequential topics discussed are data acquisition alternatives, ground-based ranging; satellite-borne systems; communications alternatives both satellite-borne and ground-based; the navigation environment, including low-frequency hyperbolic; track-keeping and navigational error; time-frequency concepts and their potential applications and probable technology. Extensive reference lists accompany each subsection of Volume II.

Volume I describes the recommended system, including the R&D program, the results of the system selection process, and study conclusions and recommendations.

Volume II--Technological Alternatives, details the description, performance, operational limitations, and requirements for each significant subsystem technological alternative studied.

Volume III--Demand and Trade Studies presents the results of the demand studies and the tradeoff analyses. The operation of each of the models is described in the appendices.

Volume IV--System Selection contains the description of the evaluation and cost models, implementation plans, phase II candidate systems, and the final system-selection results. The cost data and evaluation programs are treated in the appendices.

Volume V--Recommended Research and Development is comprised of R&D plans for operational concept evaluation, ground guidance capacity analysis, and technological feasibility demonstration programs. Also included are sections on the effect of using alternative technologies to implement various subsystems and on the criteria to be used in developing a system implementation plan.

Boeing Commercial Airplane Co. July 1975
W. D. Smith, J. E. Veitengruber, W. K. Neuberger, A. G. Osgood, G. E. Comisky
INDEPENDENT ALTITUDE MONITORING ALERT METHODS AND MODES STUDY

Boeing Commercial Airplane Co., Seattle, Washington, Technical Report No. FAA-RD-75-86, Contract DOT/FA73WA-3233, for FAA, SRDS, Washington, D.C.

In a study focussed on essentiality of pilot attention and comprehension of independent altitude monitor (IAM) alert, defines alerting philosophy of IAM, candidate concepts, and implementation schemes. Summarizes alert philosophies, and guidelines for developing and implementing IAM alert.

Ronald Braff (MITRE) July 1975
NAVIGATION PERFORMANCE REQUIREMENTS FOR REDUCING ROUTE CENTERLINE SPACING

NATO Advisory Group for Aerospace Research & Development, Neuilly-sur-Seine, France; in AGARDograph No. 209: A Survey of Modern Air Traffic Control, Vol. I.

Summarizes four major approaches to the problem of reducing route centerline spacing and the results derived from each. The four approaches are those of Boeing, the RAE, Autonetics, and MITRE.

See also MITRE WP-10599, identical title as above, by F. Dellon (MITRE) on 5 June 1974; presumably the parent paper.

Nathaniel Braverman (FAA) Fall 1971
AVIATION SYSTEM DESIGN FOR SAFETY AND EFFICIENCY

NAVIGATION: Journal of the Institute of Navigation (U.S.), Washington, D.C.; Volume 18, No. 3, Fall 1971.

Presents definitions and basic principles of design characteristics such as blunder rate, reliability, redundance, Kalman filtering, independence, integration, flexibility, and "tails" of error distributions--all in aviation system relationships. The author attempts to characterize the distribution of the tails related to blunder rate. As an introduction to study of aircraft separation or collision risk, this paper is recommended as good "armchair reading." Includes good basic graphics relevant to the subject and a tidy list of suggested reading from basic literature of the 1960's.

C. M. Britland (RAE) October 1971
A PRELIMINARY ANALYSIS OF NAVIGATIONAL PERFORMANCE OBSERVED AT STRUMBLE 1969-70

Journal of Navigation (U.K.), London, England; Volume 24, No. 4.

Third of a series of three papers in this issue entitled "Air Traffic Control Separation Standards and Navigation." Comments on some of the features of a preliminary statistical analysis of the National ATC Services (U.K.) data on track-keeping, which was collected along Green Airway 1 near the Strumble VOR. Discusses inappropriateness of the "normal" and suitability of the "exponential" characterizations of the data distribution and fit. Consistently relates the mathematical material to "the real world" which it describes; i.e., airway spacing, aircraft track-keeping, collision risk.

K. R. Britting, R. M. Hershkowitz, and D. Omathuna April 1971
THE IMPACT OF INERTIAL NAVIGATION ON AIR SAFETY

Proceedings of the National Air Meeting, Saddle Brook, N.J., April 14-16, pp. 23-46.

Includes discussion of mid-air collision risks and of error sources.

H. J. Bruns 1967
A MATHEMATICAL MODEL FOR TREATING AIRCRAFT SEPARATION PROBLEMS IN AIR TRAFFIC SAFETY CONTROL

Techniche Universitat, Berlin, IAA A69-20712, doctoral dissertation in German.

The ICAO air traffic safety regulations for preventing mid-air aircraft collisions are subjected to a mathematical analysis. Mathematical definitions and interpretations of these regulations are given. Expressions are derived for determining aircraft motions and collision danger. Collision avoidance actions are discussed in a mathematical representation. Examples are given for the practical application of the theoretical results.

H. Buhlmann 1970
MATHEMATICAL METHODS IN RISK THEORY

Published by Springer-Verlag, Berlin.

Dorothy E. Bulford (FAA-NAFEC), Compiler August 1972
COLLISION AVOIDANCE: AN ANNOTATED BIBLIOGRAPHY, SEPT. 1968 - APRIL 1972

Federal Aviation Administration, National Aviation Facilities Experimental Center (NAFEC), Atlantic City, N.J. Final Report No. FAA-NA-72-41.

R. Bulin November 1, 1974
EVOLUTION OF SYSTEMS OF CONTROL OF AIR TRAFFIC

EUROCONTROL, Brussels. In French.

Discusses NAS (U.S. National Airspace System), ARTS (U.S. Advanced Radar Terminal Service) Shanwick, beacon radar, ATC installations in the French, Dutch, and West German Systems. Reports an analysis of the reliability of installations, and takes a look at the future.

Th. J. Burgerhout February 2, 1965
NORTH ATLANTIC SEPARATION MINIMA

ICAO North Atlantic Area Systems Planning Group, working paper NAT/SPG-WP/51.

Th. J. Burgerhout October 1965
SOME NOTES ON THE COLLISION RATE OF AIRCRAFT CRUISING NOMINALLY AT ADJACENT FLIGHT TRACKS IN THE SAME VERTICAL PLANE

National Aerospace Laboratory (Netherlands); Technical Report NLR-V-1940.

Th. J. Burgerhout 1966
COMMENTS ON THE RAE TECHNICAL REPORT NO. 66156

National Aerospace Laboratory (Netherlands) NLR Report V-1953.

The RAE report upon which Burgerhout comments is "Specifying the Calibration of Static Pressure Systems for the Safe Use of 1000-foot Vertical Separation Standard in the North Atlantic Jet Traffic," by P. G. Reich and R. G. Anderson, RAE Technical Report No. 66156 (May 1966).

J. T. Burghart April 1968
NAVIGATION ACCURACY AND ATC SEPARATION STANDARDS

The Boeing Commercial Airplane Company, Seattle, Washington; Boeing Report D6-23073.

Presents a method for determining the relationships between navigation system accuracy, risk of collision, airplane traffic and required air traffic control separation standards. The model developed is exercised for a postulated North Atlantic supersonic transport environment.

CAA (UK) January 1973
EVALUATION OF INERTIAL NAVIGATION SYSTEMS - NORTH ATLANTIC REGION

Civil Aviation Authority, London, England; Directorate of Control (Plans), DCP Paper No. 65.

This report consists almost entirely of tabular and graphic analyses of navigational accuracy and track-keeping capability on some 5260 transits by aircraft of the North Atlantic region. The study eventuated from recommendations made at the NAT/V/RAN meeting of April 1970; data collection was accomplished by the U.K. with IATA during (primarily) April-July 1971 - completed by January 1972.

Results include findings that radial error rates for eastbound flights approximately double those of westbounds. The greatest difference between eastbound and westbound flights exists in the longitude parameter. There is a tendency for errors to be distributed about an axis aligned approximately NE-SW; being more pronounced for easterly flights.

Labeled DCP Paper No. 65 "Ref: CP/12/03"

John Canniff, Richard Gundersen, John Gakis (TSC) February 1975
POSITION MEASUREMENT STANDARD EVALUATION

Transportation Systems Center, Department of Transportation, Cambridge, Mass; Report No. DOT-TSC-FAA-75-17 (FAA-RD-75-26) for FAA, SRDS.

To support narrower route widths by upgrading navigational aid (NAVAID) components of the ATC system, accurate low-altitude flight-inspection data was needed detailing the performance of the VORTAC system, as well as evaluatory determination of both the identity and quality of individual components which comprise "the route-width error budget." When FAA was unable to supply accurate low-altitude flight-inspection data to RTCA Special Committee 121 for evaluation of the VORTAC system, the inadequacies and/or lack of the required empirical data base (once again) became obvious. To evaluate two specific navigation systems as one aspect in development of an accurate positioning standard, TSC modified its STOLNAV Flight Test Equipment for this evaluation of three DME receivers versus a low frequency Global Navigation system versus the FAA EAIR (extended area instrumentation radar), a single-target precision tracker with associated automated data acquisition and developed software.

"Triple DME" was found to be "an order of magnitude more accurate than the Global system." Whereas GLOBAL system accuracy varied and exhibited large random errors and quantum jumps, "Triple DME" was (in respect to accuracy) repeatable, smooth throughout, and insensitive to initial condition. While the sample was small and the test methodology mechanically straightforward and simple, the analysis and data reduction software and algorithm are interesting in relation to similar studies.

E. P. Carrigan (MITRE) April 1970
SYSTEM ERRORS RELATED TO SEPARATION STANDARDS FOR NAS STAGE A, MODEL 1

The MITRE Corporation, McLean, Virginia, MITRE Technical Report MTR-4417.

Joseph Chernof (ITT Federal Laboratories) Summer 1969
APPLICATION OF SATELLITE NAVIGATION TECHNIQUES TO MARINE AND AIR NAVIGATION

NAVIGATION: Journal of the Institute of Navigation (U.S.), Washington, D.C.; Volume 16, No. 2.

L. S. Cicolani January 1973
POSITION DETERMINATION ACCURACY FROM THE MICROWAVE LANDING SYSTEM

NASA, Ames Research Center, Moffat Field, California.

Computer Usage Co. 1975
SEPARATION CRITERIA AND CONFLICT PREDICTION

Computer Usage Co., New York; unnumbered technical report prepared for ATC Systems Branch, NAFEC.

Separation criteria for air traffic are oriented toward manual implementation. It is necessary to examine the extent to which they could be included in the automation program. This paper gathers the various criteria to show their application and to restate them in a form that will make the data processing requirements implied by them more important.

W. B. Cotton (I.F.A.L.P.A.) August 1975
THE VIEW FROM THE COCKPIT

IEEE Spectrum, Vol. 12, pp.71-74.

Centered on the effects which the Upgraded Third Generation Air Traffic Control System (UG3RD) would have on current air-to-air separation standards, and on navigation, surveillance, and communications. A critical discussion of the UG3RD shows that the system not only will do nothing to improve a pilot's capability to plan or execute more economical flight paths, but that it will erode the pilot's ability to direct those paths. Moreover, the design of flow control, metering and spacing, and ATC communications by data link decreases the pilot's awareness of the outside environment (weather phenomena, geographical position, near-term future flight path, and relationship to other aircraft in the area). The most serious criticism of the UG3RD relates to the implied philosophy of control and location of responsibility.

George Couluris, Robert Horonjeff, Adib Kanafani November 1971
AN ANALYSIS OF ALTERNATIVE OCEANIC AIR TRAFFIC CONTROL SYSTEMS

University of California, Berkeley, California, Institute of Transportation and Traffic Engineering; unnumbered technical report. See also Supplement Report (also unnumbered) by same authors, February 1972.

Develops and demonstrates a method of determining commercial aircraft trip costs in oceanic regions. Trip costs are defined as the sum of fuel, crew, and maintenance costs incurred in flight, plus the additional cost of fuel, crew, and maintenance when the aircraft is delayed due to congestion of the traffic system. Total (system) costs are defined as the sum of the trip costs, cost of implementation of an air traffic control system, cost of maintaining the system, and cost of installing the airborne equipment.

The objective of the decision maker is postulated as the implementation of the system most economical, yet capable of accommodating the forecasted demand. By comparing total costs of each system for a range of demands, alternative systems are evaluated.

Descriptions are given of the current oceanic air traffic system and of future air traffic systems, with a minimum of technical expansion. A perceptive methodology for this project's analysis is explained, and then applied. A readable and businesslike presentation. Reminds the system designer that separation standards ultimately have impact on costs.

George Couluris, Robert Horonjeff, Adib Kanafani February 1972
SUPPLEMENT TO A REPORT ON AN ANALYSIS OF ALTERNATIVE OCEANIC AIR TRAFFIC CONTROL SYSTEMS

University of California, Berkeley, California, Institute of Transportation.

The related report, An Analysis of Alternative Oceanic Air Traffic Control Systems (Couluris, Horonjeff, Kanafani), described an analysis of oceanic air traffic control systems between the coterminous United States and Hawaii. This supplement describes westbound air traffic activity on routes west and south of Hawaii, and on routes between North America and Tokyo via Alaska. The latter area is served by the North Pacific Region; the former area is served by the Central Pacific Region and South Pacific Region; and the area dealt with in the related main report is served by the East Pacific Region.

J. H. Craigie, et al. (TRW Systems Group) June 1969
NAVIGATION/TRAFFIC CONTROL SATELLITE MISSION STUDY: VOLS I, II, III

TRW Systems Group, Redondo Beach, California; Technical Report No. NASA-CR-86166 (TRW 09778-6002).

An analysis performed for NASA-ERC (Electronics Research Center) under Contract NAS 12-595, relating operational requirements in the North Atlantic post-1975 system to proposed technology for satellite usage, aircraft position determination, and communications. In three volumes: Volume I - Summary by J. H. Craigie, et al.; Volume II - System Analyses (includes the requirements) by Craigie, Dobieski, Raymond, Schultz, Mitchler, et al.; Volume III - System Concepts (describes the systems) by Craigie, Caprioglio, Kenn, Drucker, Pierce, et al. The resultant hypothesized system is discussed in detail. Each volume lists relevant references.

Warren G. Crook and Richard L. Sulzer (FAA) February 1968
SIMULATION AND ANALYSIS OF OVER-OCEAN SEPARATION ASSURANCE PROCEDURES AND DISPLAYS

Federal Aviation Administration (FAA), National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey; Technical Report No. FAA-RD-67-43.

Describes operational characteristics of the North Atlantic air traffic control system and standard operating procedures (SOP) for pilot use of air-derived separation information. Three types of air-derived separation systems were developed and tested in flight simulators: air-to-air distance measuring equipment (DME), airborne beacon range/altitude monitor, and airborne time-frequency range/altitude monitor. Through a wide diversity of aircraft intrusion situations, pilot preferences and the limitations of each system display were determined.

A. F. Crossley January 1966
ON THE FREQUENCY DISTRIBUTION OF LARGE ERRORS

Journal of the Institute of Navigation (U.K.), London, England; Vol .9, No. 1.

L. G. Culhane, B. M. Horowitz (MITRE) October 1974
GROUND-BASED COLLISION AVOIDANCE SYSTEMS FOR AIR TRAFFIC

Institute of Electrical and Electronics Engineers, Inc., New York, New York; paper in (IEEE) EASCON '74: the proceedings of the Electronics and Aerospace Convention, Washington, D.C.

Describes an early investigation of Intermittant Positive Control (IPC), using data link and improved surveillance to provide an automated collision avoidance capability. Also discusses conflict alert display for the pilot or controller or both.

J. Currier, H. Everett, K. Willis (LAMBDA) April 1969
COLLISION AVOIDANCE ALGORITHM FOR AN AUTOMATED AIR TRAFFIC CONTROL SYSTEM

LAMBDA Corporation, LAMBDA paper 33.

Discusses Intermittant Positive Control concept (IPC). Describes an algorithm that is capable of handling the detection of potential collisions and the implementation of steps to avoid them, and yet can produce a computational workload that even in a "worst case" is still within the capacity of current serial computers. The algorithm is designed to provide aircraft separation in the mixed and uncontrolled airspace through the mechanism of Intermittent Positive Control (IPC) to aircraft.

Also see paper on IPC by Currier, et al., in (IEEE) EASCON '69.

J. Currier, G. Flanagan, K. Willis (LAMBDA) October 1969
MID-AIR COLLISION AND INTERMITTANT POSITIVE CONTROL

Institute of Electrical and Electronics Engineers, Inc., New York, New York; paper by the LAMBDA Corporation in (IEEE) EASCON '69: proceedings of the Electronics and Aerospace Convention, Washington, D.C. October 27-29, 1969.

Discusses the concept of Intermittant Positive Control (IPC). Applies a mathematical model to estimate the frequency of air traffic control commands. Describes a computer algorithm which can implement IPC in a terminal 1980-1990 airspace environment.

J. W. Danaher and P. W. Bradbury June 1962
A BIBLIOGRAPHY FOR TERMINAL AREA AIR TRAFFIC CONTROL SYSTEM DESIGN

Matrix Report No. 62-9-U; The MATRIX Corporation, Philadelphia, Penna.

F. Delion (MITRE) June 5, 1974
NAVIGATION PERFORMANCE REQUIREMENTS FOR REDUCING ROUTE CENTERLINE SPACING

The MITRE Corporation, McLean, Virginia; MITRE working paper WP-10599, 46 pp.

Summarizes four agencies' approaches to the problem of reducing route centerline spacing and compares the results derived from each. The four subject studies are by Boeing, the RAE (Royal Aircraft Establishment), Autonetics, and MITRE.

An almost identical annotation describes the paper by Ronald Braff of MITRE, published July 1975 in AGARD AG-209, Vol. 1, pp. 371-389.

See Ronald Braff (same title), July 1975.

R. G. Dexter (Honeywell) 1974
AVOID-I COLLISION AVOIDANCE SYSTEM

Honeywell, Inc., St. Louis Park, Minnesota for Naval Air Development Center, Warminster, Pa.

Describes in detail the development and features of the AVOID-I Honeywell collision avoidance system.

E. J. Dickie and J. H. Briggs 1968
CURRENT AIRBORNE COLLISION AVOIDANCE PROPOSALS AND ALTERNATIVE METHODS OF ATTACK

British Air Line Pilots Association, London, England; in proceedings of the Symposium on Automation, Simulation, and Data Handling in Civil Aviation (London 1968), pp. 68-80.

Several systems proposed in the United Kingdom are discussed for four types of airspace; (1) the airways system; (2) the upper air; (3) the North Atlantic; and (4) the remaining areas for routing air traffic. The aim is to provide a control service capable of maintaining safety without unduly interfering with traffic flow. Such a system must be completely cooperative between aircraft, and capable of operating within the existing air traffic control network. The technical basis is identified as the Time/Frequency method. Since this technique is only capable of measuring range and range rate, an approach to insuring the proper altitude separation is also treated. Finally, additional complications in the vicinity of the busiest terminals are mentioned, and it is concluded that reduction of the collision danger in such areas requires improvement in the overall aircraft/ground monitoring and control system.

E. J. Dickie 1971
AIR TRAFFIC CONTROL AND NEEDS OF CUSTOMER

Journal of Navigation (U.K.), London, England; Vol. 24, p. 371.

The main function of ATC is to provide a safety service. To ind out when traffic control is required, it is necessary first to decide when and where the collision risk would be unacceptably high without ATC intervention. When mathematical criteria on collision risk are absent, the decision has to be based very largely on operational judgment and experience. In this paper, the author tries to look at ATC through the eyes of the user rather than the provider.

F. H. Ditto 1969
PARTIAL DERIVATIVES USED IN TRAJECTORY ESTIMATION

Celestial Mechanics (magazine), Vol. 1, pp. 130-140.

K. N. Dodd June 1961
AN INTRODUCTION TO AIR TRAFFIC CONTROL PROCEDURE AT PRESTWICK OCEANIC

Royal Aircraft Establishment, Farnborough, England: RAE Technical Note Math-73.

Victor S. Dolat, Joseph C. Koegler, Alan G. Nemeth (MIT) September 1972
DUAL LANE RUNWAY STUDY

Massachusetts Institute of Technology, Lincoln Laboratory, Lexington, Mass.; MIT technical report ATC-11.

Discusses issues involved in the design of dual lane runways, such as centerline spacing, high speed exits, midpoint crossing versus endpoint crossing, threshold stagger, and departure/arrival runway preference. Presents a set of preliminary criteria for dual lane runway configurations.

DOT-ATCAC July 1969
OCEANIC AREA AIR TRAFFIC CONTROL SYSTEMS

Department of Transportation, Washington, D.C.; Report to the DOT Air Traffic Control Advisory Committee (ATCAC) by the Oceanic Satellite Subcommittee.

DOT-ATCAC December 1969
REPORT OF THE DEPARTMENT OF TRANSPORTATION AIR TRAFFIC CONTROL ADVISORY COMMITTEE, VOLUME I AND VOLUME II

Air Traffic Control Advisory Committee, Dept. of Transportation, Washington, D.C.

Occasionally referred to as "the Alexander Report," from Ben Alexander (General Research Corporation), Chairman of the DOT ATC Advisory Committee. The 105-page Volume I presents Committee recommendations for an ATC system for the 1980's and beyond. The 483-page Volume II is comprised solely of nine Appendices, comprised of technical papers selected from those submitted or considered. Of these, most consider terminal area air traffic control. Of interest for enroute separation are those in Appendices C and F, particularly "Separation Hazard Criteria," by Holt and Marner (Collins Radio Co.).

DOT-ATCAC December 1969
RADAR APPLICATIONS TO POST-1980 ATC SURVEILLANCE MONITORING

Department of Transportation, Washington, D.C.; Appendix E-3 of the "Report of the DOT ATC Advisory Committee: Volume 2.

Authored by John F. Berglund of Texas Instruments, Inc., this paper was one of the inputs for ATCAC consideration which was selected for publication as an Appendix in Volume 2 of the Alexander Report. It packs into nine pages a thorough review of radar applications in the current ATC system and briefly discusses the constraints. The paper also comments briefly on aspects of radar which have been proposed or predicted for the post-1980 period. Straightforward, comprehensible, and informative.

April 1973
K. E. Duning, N. B. Hemesath, C. W. Hickok, D. G. Lammers, M. L. Goemaat
CURVED APPROACH PATH STUDY

Collins Radio Company, Cedar Rapids, Iowa; FAA SRDS Report No. FAA-RD-72-143.

Discusses application of MLS (microwave landing system) in the terminal area. While oriented to the terminal situation, this report should be of some interest to all who deal with mathematical models of ATC situations and/or with conflict path prediction and control.

Chester E. Dunmire (FAA) 1969
MATH MODEL OF THE ATC SURVEILLANCE PROCESS

Federal Aviation Administration, Systems Research & Development Service, Washington, D.C.; unpublished notes.

Chester E. Dunmire (FAA) May 1970
ESTIMATED INSTANTANEOUS AIRBORNE TRAFFIC IN THE NORTH ATLANTIC

Department of Transportation, Federal Aviation Administration, Systems Research & Development Service, Systems Analysis Division, Washington D.C., Technical Note (unnumbered), Project 197-622-02R.

Develops estimates of instantaneous airborne air traffic count (IAC) in the North Atlantic for each year through 1979. Serves a need for traffic forecasts essential for the sizing and system design of aeronautical satellites proposed for oceanic air traffic control systems. A companion document to a paper which estimates traffic in the Pacific.

Chester E. Dunmire (FAA) May 1970
ESTIMATED INSTANTANEOUS AIRBORNE TRAFFIC IN THE PACIFIC

Department of Transportation, Federal Aviation Administration, Systems Research & Development Service, Systems Analysis Division, Washington D.C., Technical Note (unnumbered), Project 197-622-02R.

Develops estimates of instantaneous airborne air traffic count (IAC) in the Pacific for each year through 1979; briefly compares Pacific (PAC) versus the North Atlantic (NAT). Serves a need for traffic forecasts essential for the sizing and system design of aeronautical satellites porposed for oceanic air traffic control systems. A companion document estimates traffic in the North Atlantic.

C. S. Durst July 1957
THE PROBLEM OF AIRCRAFT SEPARATION OVER THE ATLANTIC

Journal of the Institute of Navigation (U.K.), London, England; Vol. 12, No. 4, pp. 254-263.

C. S. Durst November 1959
ABNORMAL ERRORS AND AIRCRAFT SEPARATION OVER THE NORTH ATLANTIC

Journal of the Institute of Navigation (U.K.), London, England; Vol 12, No. 4.

J. C. Elsey (Autonetics) February 1974
CONCEPT FOR A SATELLITE-BASED ADVANCED AIR TRAFFIC MANAGEMENT SYSTEM, VOLUME V: SYSTEM PERFORMANCE

Autonetics, Division, North American Rockwell Corporation, Anaheim, California; Report No. DOT-TSC-OST-73-29, V.

See AUTONETICS.

Ralph L. Erwin, Jr (Boeing) February 1976
STRATEGIC CONTROL OF TERMINAL AIR TRAFFIC

NATO Advisory Group for Aerospace Research and Development, Neuilly-sur-Seine, France; 20th Symposium of the AGARD Guidance and Control Panel, Cambridge, Mass., May 1975; AGARD-CP-188.

Describes an advanced method of controlling air traffic in terminal areas of high-density traffic. Applies "4-D" (four-dimensional) navigation and guidance equipment, and 4-D track system; evaluates results pro and con. Of value to ATC system student/analyst: describes logic for sequencing; applies a fast-time simulation of strategic control (Los Angeles International Airport); applies an algorithm, and finally evaluates it for future modification. References: DOT-TSC-OST-3, Vols. I, IIA, IIB, III (August 1974); Strategic Control Algorithm Development. NASA/Langley Research Center (Nov. 1974); "Terminal-Configured Vehicle" Program.

H. Erzberger and H. G. Lee 1971
TERMINAL-AREA GUIDANCE ALGORITHM FOR AUTOMATED AIR TRAFFIC CONTROL

National Aeronautics and Space Administration; Technical Note NASA TN D-6773.

FAA October 1961
NORTH ATLANTIC SURVEY FLIGHT DATA-JULY 14, 1961

Federal Aviation Administration, Washington, D.C.; Traffic Analysis Branch, Working Paper, October 1961.

FAA(SRDS) April 1964
OPERATION ACCORDION: NAVIGATIONAL ACCURACIES OF CIVIL JET TRAFFIC OVER THE NORTH ATLANTIC FROM FEBRUARY 1962 TO SEPTEMBER 1963

Federal Aviation Administration, Washington, D.C.; Research and Development Service, Technical Report FAA-RD-64-52.

An early study of track-keeping, reported in two-volumes--OPERATION ACCORDION, VOLUME I, by T. Hirsh (FAA-RD-64 52,I), and OPERATION ACCORDION, VOLUME II, BY FAA, SRDS (FAA-RD-52-, II).

FAA/IGIA March 26, 1969
SIXTH AIR NAVIGATION CONFERENCE: DRAFT DOCUMENTATION FOR AGENDA ITEM 1.1

Federal Aviation Administration, Interagency Group on International Aviation, Washington, D.C.; Paper No. IGIA 72/1.107.

Draft documentation for the Sixth ICAO Air Navigation Conference (Montreal, April 9 - May 3, 1969), Agenda Item 1.1: Development of criteria for the determination of lateral and longitudinal separation minima in relation to capabilities of navigational and monitoring systems.

Furnishes documentation for use of the U.S. Delegation concerning (1) navigation system accuracy, (2) separation criteria, and (3) area navigation.

This selected-out material treats the development of criteria for the determination of lateral and longitudinal separation minima in relation to the capabilities of navigational and monitoring systems.

Attachment (1) presents a very nice description of Background/Rationale as of 1969; Attachment (1) is a paper for possible presentation by the United States at the conference.

Appendix A discusses a VOR/DME area-navigation accuracy study.

FAA/IGIA March 1969
DRAFT U.S. POSITION ON AGENDA ITEMS 1 & 6: SEPARATION OF AIRCRAFT BY A-T SERVICES AND APPLICATION OF SSR

Federal Aviation Administration, Interagency Group on International Aviation, Washington, D.C.; Paper No. IGIA 72/1-100 (March 18, 1969), 126 pages.

Provides the United States position for the ICAO Sixth Air Navigation Conference (Montreal: April 9 - May 3, 1969) for the agenda items (a) development of criteria for the determination of lateral and longitudinal separation minima in relation to the capabilities of navigational and monitoring systems; (b) development of procedures to cover the use of Mach number techniques in the application of longitudinal separation; (c) better use of airspace, with special attention to current studies of altimetry and vertical separation; and (d) the development of procedures for the separation of controlled VFR flights. Discusses application of secondary surveillance radar.

FAA/IGIA February 1970
PROVISIONS RELEVANT TO SEPARATION: IRSM STUDY GROUP

Federal Aviation Administration, Interagency Group on International Aviation, Washington, D.C.; Paper No. IGIA 83/9 (February 27, 1970) 28 pages.

Working paper of the FAA/IGIA Study Group on the Interim Review of Separation Minima (IRSM). Gives the provisions relevant to the three basic types of separation: longitudinal, lateral, and vertical.

FAA 1971
FAAR 7031.1 REDUCE SEPARATION STANDARDS IN OCEANIC AND SPARSELY POPULATED AREAS

Federal Aviation Administration; FAA Register of Requirements, FAAR 7031.1, July 26, 1951, 5 pages.

Provides background on separation standards, performance criteria, alternatives, priority, and schedule per the Department of Transportation (DOT) National Plan for Navigation. Lists 11 references on the subject of reduction of separation standards in Oceanic and sparsely populated areas.

FAA January 1972
CONCEPTS, DESIGN, AND DESCRIPTION FOR THE UPGRADED THIRD GENERATION AIR TRAFFIC CONTROL SYSTEM

Federal Aviation Administration; Washington, D.C.; Office of Engineering Development; Report FAA-ED-01-1.

See D. R. Israel (FAA), October 1974, "An Overview of the UG3rd ATC System."

FAA/IGIA February 24, 1972
SEVENTH AIR NAVIGATION CONFERENCE: DRAFT U.S. POSITION

Federal Aviation Administration, Interagency Group on International Aviation, Washington, D.C.; Paper No. IGIA 82/1.128.

Draft positions of the United States for Agenda Items 1, 4, 7, at the meeting held in Montreal, April 5-29, 1972. Item 1: Automated interchange of Air-Ground data; Item 4: SSR, Secondary Surveillance Radar; Item 7: ...Systems for Collision Avoidance. In addition, background on air-ground data link (pp.1-5); background on SSR (pp. 1-3); and background on CAS, PWI, Time/frequency technique, etc. (pp. 1-7). See also FAA/IGIA document IGIA 72/1.136: Draft Information Papers for the Seventh Air Navigation Conference.

FAA/IGIA March 20, 1972
SEVENTH AIR NAVIGATION CONFERENCE: DRAFT INFORMATION PAPERS FOR AGENDA ITEM 7

Federal Aviation Administration, Interagency Group on International Aviation, Washington, D.C.; Paper No. IGIA 72/1.136.

This document includes three information papers, with cover matter: (1) A System for Separation and Control of Aircraft using Non-synchronous Techniques (SECANT); (2) A System for Collision Avoidance using Avionic Observation of Intruder Danger (AVOID); and (3) A System for Collision Avoidance through Ground-Based Air Traffic Conflict Prediction (mainly AVAS).

The acronym AVAS represents Automatic VFR Advisory Service (see FAA project report by UNIVAC, Automatic VFR Advisory Service at Knoxville Evaluation Report, Vol. I).

FAA July 1972
LATERAL SEPARATION STUDY RESULTS, VOLUME I

Federal Aviation Administration Report No. FAA-RD-72-58.1.

FAA/NAFEC: Dorothy Bulford Compiler August 1972
COLLISION AVOIDANCE: AN ANNOTATED BIBLIOGRAPHY

Federal Aviation Administration, National Aviation Facilities Experimental Center, Atlantic City, New Jersey; Report No. FAA-NA-72-41

FAA (SRDS) January 1973
ENGINEERING AND DEVELOPMENT PROGRAM PLAN: NAVIGATION

Federal Aviation Administration, Washington, D.C., Systems Research and Development Service, Office of Engineering and Development; FAA-ED-04-1.

FAA April 1974
ENGINEERING AND DEVELOPMENT PROGRAM PLAN: AERONAUTICAL SATELLITES (AEROSAT)

Federal Aviation Administration, Washington, D.C., Office of Engineering and Development (OED), FAA Report FAA-ED-17-2.

The official version of the FAA Program Plan for the development of an Aeronautical Satellite to be introduced into the National Airspace System; The satellite is proposed to provide both aircraft position surveillance and air/ground communications relay.

FAA (DOT) March 1975
THE NATIONAL AVIATION SYSTEM PLAN 1976-1985

Department of Transportation, Federal Aviation Administration, Washington, D.C.; Report No. 1000.27, Appendix 2.

A summary report of Long Range Goals, the FAA "Ten-Year Plan" 1976-1985, including budgetary and resource considerations, and specific attention to radar, automation, communications, navaids, and system support with relation of terminal areas, enroute areas, and total system.

FAA, (ATS) January 1, 1976
AIR TRAFFIC CONTROL: OPERATIONS MANUAL

Department of Transportation, Federal Aviation Administration, Air Traffic Services, Washington, D.C.; FAA Handbook 7110.65.

This handbook prescribes air traffic control procedures and phraseology for use by "persons providing air traffic services." Primarily directed at FAA Air Traffic Service personnel at ATC Centers (En Route), Towers (Terminal Area) and Flight Service Stations.

Jack B. Feir (R. Dixon Speas Associates) 1974
EVALUATION OF ROUTING AND SCHEDULING CONSIDERATIONS FOR POSSIBLE FUTURE COMMERCIAL HYPERSONIC TRANSPORT AIRCRAFT

R. Dixon Speas Associates, Manhasset (Long Island), New York; NASA Contractor's Report Number NASA-CR-132632 for National Aeronautics and Space Administration (Washington, D.C.).

Indirectly related to separation studies, this report discusses travel markets and the ability of airlines to service them with efficient utilization and productivity. This report considers city pairs, sonic boom restriction, sonic boom constraints, airport curfews, potential daily utilization, and aircraft productivity.

T. Felisky February 1974
CONCEPT FOR A SATELLITE-BASED ADVANCED AIR TRAFFIC MANAGEMENT SYSTEM, VOLUME VII: SYSTEM COST

Autonetics Division, North American Rockwell Corporation, Anaheim, California, DOT-TSC-OST-73-29, VII; for Transportation Systems Center.

See AUTONETICS.

December 1963
Lyle D. Filkins, Joseph W. Little, James O'Day, and Robert E. Scott
STUDY AND ANALYSIS OF POSITION DATA ACQUISITION TECHNIQUES FOR OVER-OCEAN AIR TRAFFIC CONTROL

University of Michigan, Ann Arbor, Michigan; Report No. FAA-RD-64-6.

Lyle D. Filkins and Joseph W. Little (Michigan) November 1964
STUDY OF AIRCRAFT SEPARATION CRITERIA

University of Michigan, Ann Arbor, Michigan; FAA Report FAA-RD-64-113.

A study of (1) identification of the significant factors that influence enroute separation minima for aircraft in flight and (2) development of a mathematical model that functionally relates these factors. Both radar and nonradar modes of ATC are considered.

D. E. Findley June 1972
SATELLITE CONSIDERATIONS IN FUTURE AIR TRAFFIC CONTROL SYSTEMS

NATO-AGARD, Neuilly-sur-Seine, France.

Paper in AGARD-CPP-105, Conference Proceedings No. 105 of the NATO Advisory Group for Aeronautical Research and Development, June 1972, pages (30-1) through (30-9).

Capt. Alfred E. Fiore, USNR, and Dr. Paul Rosenberg Fall 1970
EARTH SATELLITE SYSTEMS FOR MARINE AND TRANSOCEANIC NAVIGATION AND TRAFFIC CONTROL

NAVIGATION: Journal of the Institute of Navigation (U.S.), Washington, D.C.; Vol. 17, No. 3.

An authoritative, argumentative description of the situation in anticipation of explosive traffic growth. Somewhat of a sales pitch for satellites in the system, but good, reading.

Paper presented at the Quadripartite Meeting of the European Navigation Institutes, Rome, Italy, May 11-14, 1970.

P. D. Flanagan and K. E. Willis March 1969
FREQUENCY OF AIRSPACE CONFLICTS IN THE MIXED TERMINAL ENVIRONMENT

LAMBDA Corporation, prepared for DOT ATC Advisory Committee under Contract DOT-05-A9-032. Also published December 1969 as Appendix C, DOT ATC Advisory Committee Report, Volume 2.

Describes a method for estimating the number of "close approaches" of aircraft in a dense terminal environment. The purpose of developing such estimates is to determine the computational workload involved in implementing a system for detecting potential airspace conflicts. The paper provides upper bounds for two parameters important to automated air traffic control: (a) the expected number of potential collision calculations to be performed per hour; and (b) the expected number of course-change commands per hour to be sent to the aircraft to avoid collisions. A model is developed to represent the terminal area.

J. H. Flanders and P. A. Grundy November 1971
PWI SYSTEMS SURVEY: A BIBLIOGRAPHIC REVIEW OF PWI AND CAS DOCUMENTS

Intermetrics Inc., Cambridge, Mass. for DOT Transportation Systems Center, Cambridge, Mass.

Review of 176 documents related to Proximity Warning Indicator (PWI) and Collision Avoidance System (CAS).

L. J. Fogel June 1955
AN ANALYTICAL APPROACH TOWARD AIR TRAFFIC CONTROL

IRE Transactions on Aeronautical and Navigational Electronics, Vol. AWE-2, No. 2.

H. T. Freedman, et al. February 1974
CONCEPT FOR A SATELLITE-BASED ADVANCED AIR TRAFFIC MANAGEMENT SYSTEM, VOLUME I: SUMMARY

Autonetics Division, Rockwell International Corp., Anaheim, Cal.; Technical Report No. DOT-TSC-OST-73-29, I, for DOT Transportation Systems Center, Cambridge, Mass.

Edward L. Fritz (F.I.L.) June 1955
SOME REALISTIC MATHEMATICAL ASPECTS OF AIR TRAFFIC CONTROL

Franklin Institute Laboratories for Research and Development, Philadelphia, Pa.; Working Paper No. 7, Project 2384.

Technical Report for (U.S.) Civil Aeronautics Administration (later Federal Aviation Administration) Technical Development Center, Indianapolis, Indiana.

Edward L. Fritz ((F.I.L.) December 1955
SETTING SEPARATION STANDARDS FOR ENROUTE AIRCRAFT

Franklin Institute, Philadelphia, Pa.; Working Paper No. 6, Project A-1816-1.

Defines the parameters needed for a logical approach to separation standards for enroute air traffic control. Rules are given for setting up realistic separation limits. Rules are given for setting up working separations based on the accuracy of estimates, rather than minimum reported separations. A funnel concept is developed of ever-decreasing separations as newer estimates are made on a flight. It is shown that the accuracy of position reports is far more important than their frequency.

John E. Gaffney, Jr. (IBM, Federal Systems Division) Summer 1969
TIME-DIFFERENCE POSITION-DETERMINATION SYSTEM FOR AEROSPACE AND TERRESTRIAL APPLICATIONS

NAVIGATION: Journal of the Institute of Navigation (U.S.), Washington, D.C., Vol. 16, No. 2.

G.A. Gagne and R. M. Hershkowitz August 1972
OCEANIC SURVEILLANCE AND NAVIGATION ANALYSIS, FY-72

Transportation Systems Center, Department of Transportation, Cambridge, Mass.; for FAA, SRDS, Washington, D.C.; DOT-TSC-FAA-72-26 (FAA-RD-72-142).

An informative report for studies of ATC separation or oceanic ATC. With focus on oceanic ATC, discusses (a) lateral safety, (b) longitudinal and vertical dimensions, (c) aided-inertial navigation, as they are related to satellite surveillance. Considers a methodology (developed by SCI) for relating collision risk of the NAT track system to the general characteristics of the on-board navigation system. Discusses the Reich Collision Risk Model and other models.

See also DOT-TSC-FAA-71-13, by Hershkowitz, and FAA-RD-73-88 by SCI (Systems Control, Inc., Palo Alto, California). Each was published under the same title: Oceanic Surveillance and Navigation Analysis. Also see (DOT)-TSC-FAA-72-26 (same title).

Leo J. Garodz (NAFEC) October 1975
FLIGHT TEST INVESTIGATION OF THE VORTEX WAKE CHARACTERISTICS BEHIND A BOEING 727 DURING TWO-SEGMENT AND NORMAL ILS APPROACHES

National Aeronautics and Space Administration, Edwards Flight Research Center, California; prepared jointly with FAA-NAFEC (National Aviation Facilities Experimental Center), Atlantic City, N.J.; NASA-TM-X-72908, FAA-NA-75-151.

Flight tests to evaluate the wake vortex characteristics of the Boeing 727. See other wake vortex studies by Leo Garodz (NAFEC) in FAA-RD technical reports in the 1970's.

P. C. Gaudillere January 1958
VISUAL AND ELECTRONIC METHODS OF AVOIDING COLLISION

Journal of the Institute of Navigation (U.K.), London, England; Vol. 11, No. 1.

General Precision Systems Ltd. April 1965
ATC SYSTEM CAPACITY AND NAVIGATIONAL REQUIREMENTS FOR THE NORTH ATLANTIC AND CONTINENTAL TRANSITION AREAS

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Procedings of the 16th IATA TECHNICAL CONFERENCE (Miami, April 1965); paper presented by General Precision Systems Limited, U.K. Working paper WP-54. Also published Journal of the Institute of Navigation (U.K.), Vol. 18, No. 4, October 1965.

Examines navigational principles and operational objectives with consideration of ATC system capacity, navigational accuracy, and operational economy. Navigational errors are discussed, and a minimum navigational performance specification is developed.

BFS (Germany)-SRG October 1972
COLLECTION OF DATA REGARDING ACCURACY OF ATC AND PILOT ESTIMATES FOR POSSIBLE APPLICATION IN A LONGITUDINAL SEPARATION MODEL

ICAO, Review of General Concept of Separation Panel, Working Group "C"; Fourth Meeting, working paper RGCSP-C-unnumbered.

The air traffic control authority of the Federal Republic of Germany is the Bundesanstalt fur Flug-Sieberung (BFS).

Frank V. Giallanza, Charles P. Giallanza, and James C. Brown May 1973
PROGRESS REPORT VERIFICATION IN AN AUTOMATED OCEANIC AIR TRAFFIC CONTROL SYSTEM

Meta Systems, Inc., Santa Clara, California, Report FAA-RD-73-70.

An algorithm was developed to verify the contents of progress reports input to an automated oceanic air traffic control system. Position related data in the aircraft progress report was checked for consistency with the pilot's filed flight plan.

See also (by the same authors): FAA-RD-73-71, Remote Entry of Progress Report; FAA-RD-73-72, Flight Plan Position Extrapolation; and FAA-RD-73-73, Potential Conflict Prediction.

Frank V. Giallanza, Charles P. Giallanza, and James C. Brown May 1973
FLIGHT PLAN POSITION EXTRAPOLATION IN AN AUTOMATED OCEANIC AIR TRAFFIC CONTROL SYSTEM

Meta Systems, Inc., Santa Clara, California, Final Report FAA-RD-73-72.

Discusses the periodic updating of aircraft flight position based on stored flightplan and current meteorological data. The method applies laws of spherical geometry to great-circle course computation and extrapolation of aircraft progress,

See also (by the same authors): FAA-RD-73-70, Progress Report Verification, FAA-RD-73-71, Remote Entry of Progress Reports; and FAA-RD-73-73, Potential Conflict Prediction.

Frank V. Giallanza, Charles P. Giallanza, and James C. Brown May 1973
POTENTIAL CONFLICT PREDICTION AND ASSOCIATED FUNCTIONS FOR OCEANIC AIR TRAFFIC CONTROL AUTOMATION

Meta Systems, Inc., Santa Clara, California, Final Report FAA-RD-73-73.

Algorithms were developed to determine potential conflicts over an oceanic airspace. Associated functions used by air traffic controllers to resolve conflict situations are also described.

See also (by the same authors): FAA-RD-73-70, Progress Report Verification; FAA-RD-73-71, Remote Entry of Progress Reports; and FAA-RD-73-73, Flight Plan Position Extrapolation.

Frank V. Giallanza, Charles P. Giallanza, and James C. Brown December 1973
REMOTE ENTRY OF PROGRESS REPORTS IN AN AUTOMATED OCEANIC AIR TRAFFIC CONTROL SYSTEM

Meta Systems, Inc., Santa Clara, California, Report FAA-RD-73-71.

Discusses requirements and procedures to input voice-derived progress reports from aircraft (or other remote source) into an automated oceanic air traffic control system. Describes in detail message formats and procedures to communicate with Aeronautical Radio, Inc. (ARINC). Functional flowcharts to illustrate the process supplement the description.

See also (by the same authors): FAA-RD-73-70, Progress Report Verification, FAA-RD-73-72, Flight Plan Position Extrapolation; and FAA-RD-73-73, Potential Conflict Prediction.

C. A. Gilbert May 1970
AN AIRBORNE COMPUTER SYSTEM FOR NAVIGATION AND TRAFFIC CONTROL

Paper presented to the International Federation of Air Traffic Controllers Associations, 9th Annual Conference, Montreal, Canada, 11-14 May, 1970, 17 p.

The capability which 3-D RNAV gives pilots in following precisely desired flight paths in three dimensions, introduces new factors which may contribute materially in helping to reduce mid-air collisions.

F. N. D. Gilbert and P. L. Batrum 1970
A CONFLICT PREDICTION ALGORITHM FOR USE IN PROCEDURAL DOMESTIC AIRSPACE

International Federation of Air Traffic Controllers Associations, Montreal, Canada; proceedings of the 9th Annual Conference.

Judith F. Gilsinn and Douglas R. Shier May 1976
MATHEMATICAL APPROACHES TO EVALUATING AIRCRAFT VERTICAL SEPARATION STANDARDS

National Bureau of Standards (U.S.), Washington, D.C., Report No. NBSIR 76-1067 for FAA, Office of Systems Engineering Management. Published by FAA (OSEM), Washington, D.C., as Report FAA-EM-76-12.

Anticipating the possibility of reducing the separation standard above flight level 290 from at least 2000 feet (vertically) to a small vertical separation minimum, this study was performed by the National Bureau of Standards, Operations Research Section, Applied Mathematics Division, for the FAA Office of Systems Engineering Management.

This report details many of the components of vertical position error and classifies them into three major categories: static pressure system error, altimeter instrument error, and pilot response error. Two models for use in evaluating separation standards, the root sum of squares (RSS) approach, and the Reich collision risk model, are described, together with their respective advantages and disadvantages. A final section includes recommendations for a carefully designed data collection effort, and discusses potentially important considerations for such a design.

L. L. Goertzen October 1972
ALTITUDE-AIDED RADAR TRACKING

Pacific Missile Range, Point Mugu, California, Technical Report No. PMR-TP-72-10.

A. Golden February 1966
RADAR SEPARATION OF CLOSELY SPACED TARGETS

IEE Spectrum, Vol. 3, No. 2.

Interesting treatment with numerous graphics. "The capability of a hypothetical radar against attacks by closely spaced aircraft may be examined in geometric terms, and the results can be plotted graphically. A pulse Doppler type radar appears to be essential in this situation. Separation is still possible if sufficient Doppler resolution is available to permit the measurement of the small changes in velocity that will be required for the aircraft to maintain formation." Discusses a fire-control weapons system radar problem.

A. J. Goldman, W. A. Steel, and W. A. Horn April 1971
CONTINUED ANALYSIS OF A CAPACITY CONCEPT FOR RUNWAY AND FINAL-APPROACH PATH AIRSPACE

National Bureau of Standards, Washington, D.C., Report No. NBS-10589, Contract DOT-FA69WI-166, April 1971, 157 p.

In a previous study, a "Maximum Throughput Rate" concept for the capacity of a runway and its associated final-approach path airspace was developed, represented by a simple mathematical formula, and given illustrative application in the context of a stream of IFR CTOL landings. In this sequel, the capacity formulation is generalized to admit separation minima which are dependent on aircraft type. Algebraic tests are developed to aid in indentifying those situations in which in-air separation requirements are the dominant limiters of capacity, and also the opposite extreme, in which long occupancy of the runway by arriving planes is the critical bottleneck. Simplified upper bounds on (numerical) capacity are derived. An analysis is made of the capacity-increasing potential of certain types of deviation from first-come-first-served acceptance of aircraft.

H. C. N. Goodhart July 1966
NORTH ATLANTIC SEPARATION: ASSESSING THE REAL COLLISION RISK

Flight International, Vol. 90.

H. C. N. Goodhart Spring 1968
COLLISION RISK AND CONTROLLED AIRSPACE

Journal of the Guild of ATC Officers (U.K.), Vol. 4, No. 5.

Air collision is an inescapable risk in flying; the question is simply what safety level is acceptable and how shall the required level be achieved. This paper reviews the concepts of collision risk, separation standards and controlled airspace, and lists the possible measures to keep the risk to the required level.

P. A. Grafton (Date missing)
ANALYSIS OF THE AVOIDANCE OF COLLISION BETWEEN AIRCRAFT ON CURVILINEAR FLIGHT TRAJECTORIES

U.S. Naval Research Laboratory, Report 5344.

Dunstan Graham, Warren F. Clement, and Lee Gregor Hoffman June 1971
MANUAL CONTROL THEORY APPLIED TO AIR TRAFFIC CONTROLLER-PILOT COOPERATION

Seventh Annual NASA/University Conference on Manual Control, June 2-4, 1971; University of Southern Cal., Los Angeles.

Since a prototype problem is developed in detail, including appropriate modelling, this article is recommended as orientation reading (very straightforward) for those undertaking modelling in ATC system/separation studies. Discusses system parameters/performance measures (for safe separation standards on independent IFR runways); runway configurations, aircraft type categories (CTOL, VTOL, RTOL, STOL); airborne equipment (flight director, automatic coupled approach); gust/wind/wind shear environment; data acquisition capabilities (e.g. ASR); operational pattern (front course/back course, etc.); blunder frequency; controller intervention rules, controller response, pilot response; "possibly still other factors." Cites ATCAC Report (1969): "Major improvements in airport capacity must be achieved," embarks on thesis "augmentation of runway capacity by ...reduced separation standards will demand the utmost performance of a truly-named man-machine system. ...manual control theory (can) contribute to the determination of safe separation standards for terminal air traffic control; ...performance of the system with respect to separation standards is not critically sensitive to the performance of the air traffic controller and the pilot; ,...a blunder is a random process in the sense that its occurrence is probabilistic; but for our purposes (prototype problem) ...it is a single deterministic function of time."

William Gracey and JoAnn Shipp April 1961
RANDOM DEVIATIONS FROM CRUISE ALTITUDE OF A TURBOJET TRANSPORT AT ALTITUDES BETWEEN TWENTY AND FORTY-ONE THOUSAND FEET

National Aeronautics and Space Administration (NASA), NASA Technical Note TND-820.

William Gracey March 1963
ANALYSIS OF THE EFFECT OF ALTIMETER SYSTEM ACCURACY ON COLLISION PROBABILITY

National Aeronautics and Space Administration (NASA), NASA Technical Note TND-1627.

V. P. Gupta (MITRE) March 1976
CAPACITY IMPACT OF REVISING AIRCRAFT CATEGORIES AND FINAL APPROACH SEPARATION STANDARDS

The MITRE Corporation, McLean Virginia; MITRE Technical Report MTR 7183, for DOT FAA/OSEM under Contract DOT-FA70WA-2448.

Longitudinal separation standards recently revised to vary according to aircraft weight classifications have been cooperatively adjusted from a 2-category United States system and a 4-category Canadian system to a common (to United States and Canada) 3-category system. In turn, this implies possible modification through international agreement. This paper compares the capacity impact of various alternatives, and relates the discussion to aircraft wake/vortex studies. The specific argument related to this program is accompanied by capacity model and capacity analysis discussion of a more general interest.

R. E. Hagerott and W. J. Weiss (ATCAC) February 7, 1969
AIRCRAFT SEPARATION MINIMA, STANDARDS, AND CRITERIA AND RELATED NATIONAL AIRSPACE SYSTEM COMPONENT VARIABLES

Transportation Systems Center, Department of Transportation, Cambridge, Mass.; an unpublished working paper.

This working paper was prepared for the DOT ATC Advisory Committee by ATCAC Group III, but it was not published per se in Volume II of the ATCAC Report (1969).

A. L. Haines February 1973
REDUCTION OF PARALLEL RUNWAY REQUIREMENTS

The MITRE Corporation, McLean, Virginia; MITRE Technical Report MTR-6282.

A. L. Haines January 1975
REQUIREMENTS FOR 3500-FOOT SPACINGS FOR SIMULTANEOUS PARALLEL IFR APPROACHES

The MITRE Corporation, McLean Virginia; MITRE Technical Report MTR-6841.

A. L. Haines, B. M. Horowitz, and A. P. Smith May 1975
A GENERAL MODEL FOR SEPARATION STANDARD ASSESSMENT

The MITRE Corporation, McLean, Virginia; MITRE Technical Report MTR-6909 for FAA OSEM under Contract DOT FA70WA-2448.

MITRE has concluded (MTR-6767) that none of the methodologies for study of oceanic separation standards in a system using satellites is entirely satisfactory; and that a logical "General Model" is needed to "motivate and assist present oceanic needs...(and) be nearly always applicable to past and future separation standard assessment models." MTR-6909 presents the basic elements of a logical structure of a General Model for separation standard assessment and illustrates how some existing models fit within its framework. Includes discussion of the Reich North Atlantic Model, the Parallel Runways Model, and recommended use of the General Model.

J. C. Hansen and D. J. Maxwell April 1971
ANALYTICAL MODEL FOR NAVIGATION AND AIR TRAFFIC CONTROL

Institute of Navigation (U.S.), Washington, D.C.; Proceedings of the National Air Meeting, Saddle Brook, N.J., April 14-16, 1971.

Presents an analytical model intended for application in the design of an ATC system for the NAT region. The model is exercised to demonstrate the effect of several parameters on lateral separation standards for parallel flight lanes. The introduction of a satellite navigation system allows a substantial reduction in lateral separation.

J. B. Heath (Board of Trade) January 1971
THE COSTS AND BENEFITS OF AIR NAVIGATION AND CONTROL SYSTEMS

Journal of Navigation (U.K.), London, England; Vol. 24, No. 1.

R. M. Hershkowitz, D. O'Mathuna, and K. R. Britting May 1971
THE IMPACT OF INERTIAL NAVIGATION ON AIR SAFETY

Transportation Systems Center, Department of Transportation, Cambridge, Mass.; Technical Report No. DOT-TSC-FAA-71-5; also in NAVIGATION, Vol. 18, No. 3, Fall 1971, pp. 298-307, journal of the Institute of Navigation (U.S.); also published by the Institute of Navigation (U.S.), April 1971, in Proceedings of the National Air Meeting, Saddle Brook, N. J., April 14-16, 1971.

Includes discussion of error sources and mid-air collision risks. Analyzes the impact of inertial navigation on air safety.

Ronald M. Hershkowitz May 1971
COLLISION RISK MODEL FOR THE NAT REGION

Transportation Systems Center, Department of Transportation, Cambridge, Mass.; Technical Report No. DOT-TSC-FAA-71-6.

Reviews and summarizes the essential features of the collision risk model used to analyze the effects of separation standards on safety in the North Atlantic. The derivation of the model is traced from a set of basic assumptions to formulations of various philosophies and a brief set of conclusions and recommendations for future work.

Ronald M. Hershkowitz June 1971
OCEANIC SURVEILLANCE AND NAVIGATION ANALYSIS

Transportation Systems Center, Department of Transportation, Cambridge, Mass.; Final Report No. DOT-TSC-FAA-71-13

Three major efforts are reviewed and discussed: (1) a tutorial summary of the NAT/SPG collision risk model; (2) a study of the impact of inertial navigation on air safety; and (3) an investigation of the modeling techniques required to assess the effect of ATC satellite surveillance on separation standards in the North Atlantic region.

See also Gagne and Hershkowitz, FAA-RD-72-142 (TSC-FAA-72-26), published August 1972; Stepner, Heine, Sorensen, FAA-RD-73-88, published 1973; and TSC-FAA-72-26; all under similar titles.

R. M. Hershkowitz October 1971
AIR TRAFFIC CONTROL FOR THE NORTH ATLANTIC

Proceedings of the IEEE Fall Electronics Conference, Chicago, Illinois, October 18-20, 1971, pp. 261-269.

Summary of the essential features of a North Atlantic (NAT) traffic study undertaken at the Transportation Systems Center. The emphasis is on summarizing the important aspects of the collision risk model currently used to assess safety standards. This model, derived by Reich and adopted and extended by the North Atlantic Systems Planning Group, relates accident levels to aircraft and airspace parameters. Extensions of the original model are briefly discussed, and preliminary results are presented. These extensions seek to include the effects of inertial navigation and positive air traffic control on the routing structure in the NAT region.

Arthur Hilsenrod October 1964
DEVIATIONS FROM STANDARD ALTITUDE SEPARATION DUE TO ATMOSPHERIC TEMPERATURE VARIATIONS

Federal Aviation Administration Systems Research and Development Service, NAFEC, Atlantic City, N.J.; memorandum report.

FAA memorandum reports are difficult to locate; suggest try NAFEC Library.

P. M. Hinchcliffe (U.K., Boscombe Down) April 1965
AN EXAMINATION OF THE POTENTIAL ACCURACY OF A NAVIGATION TECHNIQUE FOR NORTH ATLANTIC FLIGHTS BASED ON LORAN-A AND A DOPPLER/G.M. COMPASS AUTOMATIC DEAD-RECKONING SYSTEM

International Air Transport Association, Montreal, Canada; in AIRCRAFT: NAVIGATION: procedings of the 16th IATA TECHNICAL CONFERENCE, (Miami); working paper WP-73.

Conference objectives were to establish navigational principles, operational objectives, and airline preferences, for long-range (and transition) systems. Flight Lieutenant Hinchcliffe, of the U.K. Aeroplane and Armament Experimental Establishment, Boscombe Down, examines techniques based on Loran-A and automatic dead-reckoning.

Irving Hirsh, Ronald Braff, and O. Marie DesRosier April 1964
OPERATION ACCORDIAN: FINAL REPORT, I

Federal Aviation Administration, Systems Research and Development Service, Technical Report FAA-RDX-64-52,I.

Irving Hirsh and Ronald Braff April 1964
OPERATION ACCORDIAN: FINAL REPORT, II

Federal Aviation Administration, Systems Research and Development Service, Technical Report FAA-RDX-64-52,II.

Reports on the study of navigational accuracies of civil jet traffic over the North Atlantic during an 18-month period, 1962-1963.

William C. Hoffman and J. Zvara (Aerospace Systems), June 1971
W. M. Hollister and K. R. Britting (MIT)
A HYBRID NAVIGATION SIMULATION FOR NORTH ATLANTIC ROUTES

Institute of Navigation (U.S.), Washington, D.C. report of 29th Annual Meeting of the ION, St. Louis, June 19-21, 1973.

Reviews current air traffic operations on the North Atlantic routes. Relates the need for improved navigational accuracy to the need for increased capacity compatible with adequate separation standards. Discusses hybrid navigation, which combines information from two or more navigational sources. A digital computer simulation program "NATNAV" (North Atlantic Navigation) was developed to evaluate the performance of various hybrid navigation system configurations applicable to the NAT region. The covariance matrix error analysis method was used to simulate aided-inertial navigation system error histories, using the optimum recursive Kalman filter to incorporate independent measurements of position or velocity. Some computer results are presented.

William C. Hoffman, W. M. Hollister, and R. W. Simpson April 1972
FUNCTIONAL ERROR ANALYSIS AND MODELING FOR ATC SYSTEM CONCEPT EVALUATION

Aerospace Systems, Inc., Burlington, Mass.; for DOT, Transportation Systems Center, Cambridge, Mass.; Technical Report No. ASI-TR-72-9 (DOT-TSC-212-72-1).

January 1973
William C. Hoffman, Walter M. Hollister, and Kenneth R. Britting
NORTH ATLANTIC (NAT) AIDED INERTIAL NAVIGATION SYSTEM SIMULATION: VOLUME I, FINAL TECHNICAL REPORT

Aerospace Systems, Inc., Burlington, Mass., for DOT Transportation Systems Center, Cambridge, Mass.; Technical Report No. ASI-TR-73-14, (DOT-TSC-473-73-1).

First volume of a two-volume report. Reviews applications of hybrid navigation systems in air traffic operations over the North Atlantic (NAT). Describes development of a digital computer simulation program (NATNAV = North ATlantic NAVigation) to evaluate performance of proposed navigation systems. Describes error models developed for aided-inertial navigation systems with external measurements from Doppler radar, Omega, satellite-ranging, or air data. Presents analysis techniques and mathematical models.

Includes a lengthy and sturdy bibliography; q.v.

William C. Hoffman and Kathryn G. Bowie January 1973
NORTH ATLANTIC (NAT) AIDED INERTIAL NAVIGATION SYSTEM SIMULATION: VOLUME II, COMPUTER PROGRAM NATNAV USER'S MANUAL

Aerospace Systems, Inc., Burlington, Mass., under Contract DOT-TSC-473 for DOT Transportation Systems Center, Cambridge, Mass.; Technical Report No. ASI-TR-73-14 (DOT-TSC-473-73-2).

Second volume of a two-volume report. Volume II describes the digital computer simulation program NATNAV (North Atlantic Navigation) developed by ASI to analyze various inertial navigation systems using external measurements of position and/or velocity from OMEGA, Air Data, Doppler Radar, and/or Satellite Surveillance with two-satellite ranging. A complete listing of NATNAV (in FORTRAN IV) is included (Section XI). Volume I contains a complete description of mathematical models and analysis techniques implemented in the NATNAV simulation.

J. M. Holt and R. M. Anderson March 1968
ANALYSIS OF WARNING TIMES FOR COLLISION AVOIDANCE SYSTEMS

Institute of Electrical and Electronics Engineers, Inc., New York, New York; IEEE Transactions on Aerospace and Electronic Systems, Vol. AES-4, No. 2.

J. M. Holt, L. Beldon, and W. Jameson (Collins) July 1968
COMPUTER/SIMULATION STUDY OF AIR-DERIVED SEPARATION-ASSURANCE SYSTEMS IN MULTIPLE AIRCRAFT ENVIRONMENT

Collins Radio Co., Cedar Rapids, Iowa; 186 pp; technical report under Contract FA-WA-4598 (Project FAA-241-003-01C), for FAA, SRDS, Washington, D.C.

The three subject areas treated are hazard evaluation in maneuvering environments, air-to-air oscillator synchronization, and minimum systems for general aviation. Hazard evaluation is analyzed in both the horizontal and vertical dimensions.

J. M. Holt and G. R. Marner — December 1968
SEPARATION HAZARD CRITERIA — Modified May 1969

Collins Radio Company, Cedar Rapids, Iowa.

A general treatment of collision hazards useful in several applications. As an analysis tool, to permit the optimization of ATC systems with regard to collision safety, and to permit comparisons between different proposed systems. As an aid to the review of separation standards when changes in procedures, types of available data, or data accuracy are planned.

Also published as Appendix C, Vol. 2, Report of DOT ATCAC, Department of Transportation--ATC Advisory Committee. See also Holt and Marner, "Separation Theory in ATC System Design" (Collins, March 1970).

J. M. Holt and G. R. Marner (Collins Radio Co.) — November 1969
COMPUTER/SIMULATION STUDY OF AIR-DERIVED SEPARATION-ASSURANCE SYSTEMS IN MULTIPLE AIRCRAFT ENVIRONMENT

Collins Radio Company, Cedar Rapids, Iowa; Final Report FAA-RD-69-31, for FAA, SRDS, Washington, D.C., under Contract FA-WA-4598.

Reexamines earlier concepts and conclusions (reported in three interim reports) in the light of upcoming changes to ATC and the possibility of ground-based collision avoidance.

J. M. Holt and G. R. Marner (Collins Radio Co.) — December 1969
SEPARATION HAZARD CRITERIA

Collins Radio Company, Cedar Rapids, Iowa; published as Appendix C, Vol. 2, Report of DOT ATCAC (Department of Transportation--ATC Advisory Committee).

See also same reference published by Collins Radio Company in December 1968 and, as modified, in May 1969.

J. M. Holt and G. R. Marner (Collins Radio Co.) — March 1970
SEPARATION THEORY IN AIR TRAFFIC CONTROL SYSTEM DESIGN

Institute of Electrical and Electronics Engineer, New York, New York; Proceedings of the IEEE, Vol. 58, No. 3.

A general treatment of collision hazard which expresses the relationship between separation standards, velocity and acceleration, surveillance accuracy, communication delays, sampling frequency, maneuver severity, and intervention frequency. An example is given of separation standards achievable through the use of an upgraded beacon system. The relations presented permit optimization

of air traffic control systems with regard to collision safety and will permit comparisons between different proposed systems. They should assist in reviewing separation standards when changes in procedures, types of available data or data accuracy are planned. Further, the procedures outlined could, in hazard evaluation, aid the air traffic control process. See Holt and Marner (1968/1969) "Separation Hazard Criteria."

J. M. Holt (McDonnell-Douglas) Spring 1974
SAFE SEPARATION IN CONTROLLED FLIGHT

NAVIGATION: Journal of the Institute of Navigation (U.S.), Washington, D.C., Vol. 21, No. 1.

J. M. Holt and R. H. Hamilton (McDonnell-Douglas) Winter 1974-1975
SURVEILLANCE VELOCITY MEASUREMENTS WITH LEAST MAXIMUM ERROR

NAVIGATION: Journal of the Institute of Navigation, (U.S.), Washington, D.C.; Vol. 21, No. 4.

To ensure safety on parallel airpaths, the surveillance separation assurance function used for automated air traffic control is optimized by deriving the best possible compromise between noise-induced and acceleration-induced errors as a function of measurement accuracy, acceleration magnitude, and sampling frequency. It is found that an error allowance of 30 knots would be adequate with 97.7 percent confidence, provided that 58 position measurements, spaced at 0.1-second intervals, were available. Since very fine measurements are required to obtain small speed measurement allowances, it is not possible to achieve separation standards through surveillance-measured speed only.

Dr. Barry M. Horowitz (MITRE) September 1975
THE ACAS DESENSITIZATION PROBLEM AND A POSSIBLE APPROACH TO DESENSITIZATION

The MITRE Corporation, McLean, Virginia; MITRE Technical Report MTR-7021 for DOT-FAA/OSEM

ACAS is the Airborne Collision Avoidance System concept (such as those under development by McDonnell-Douglas, RCA, or Minneapolis-Honeywell). FAA is considering the use of ACAS to augment ATC systems that "are aimed at providing separation assurance." Limitations are imposed on ACAS performance by the need for current pilot procedures, ACAS, and the current ATC system to coexist in the same airspace. Compromises in the collision protection afforded by ACAS take the form of desensitization of the ACAS system. This paper describes the desensitization and discusses the problem.

W. F. Horton, Jr. January 1975
CONFLICT PREDICTION THEORY FOR AUTOMATED IFR TRAFFIC CONTROL

The MITRE Corporation, McLean, Virginia,; MITRE working paper WP-10911.

J. S. Hunter, G. A. Hazelrigg Jr., and S. Claudet April 1974
AN ANNOTATED BIBLIOGRAPHY ON TARGET LEVEL OF SAFETY, COLLISION RISK, AND COST-BENEFIT ANALYSIS RELEVANT TO SEPARATION STANDARDS

Dept. of Civil and Geological Engineering, Princeton University, Princeton, New Jersey.

IATA October 1967
AIR TRAFFIC SURVEILLANCE THROUGH SATELLITES IN THE NAT OCEANIC AREA: A COST/BENEFIT METHODOLOGY

NATO/ASTRA, Neuilly-sur-Seine, France; presented by the International Air Transport Association at the second meeting of the NATO panel on Application of Satellite Techniques Related to Aeronautics (as working paper 13, ASTRA/II).

IATA January 1960
ALTIMETRY AND THE VERTICAL SEPARATION OF AIRCRAFT

International Air Transport Association, Montreal, Canada.

IATA April 1965
AIRCRAFT NAVIGATION: THE SIXTEENTH IATA CONFERENCE

International Air Transport Association, Montreal Canada.

135 papers are summarized, including:
IATA 16/WP-16: Proposals for the Mathematical Formulation of Separation Standards, R. N. Lord, U.K., College of Aeronautics;
IATA 16/WP-41: A Preliminary Analysis of the North Atlantic Route Structure and Navigation System Error, M. E. Schucart and J. B. Arnett (North American Aviation, Inc.);
IATA 16/WP-54: ATC System Capacity and Navigational Requirements for the North Atlantic and Continental Transition Areas, General Precision Systems Limited;
IATA 16/WP-78: The ATC Requirement for Navigational Capability Over the North Atlantic, U.K., National Air Traffic Control Services (Ministry of Aviation U.K.);
IATA 16/WP-87: An ATC Survey of North Atlantic Navigation Problems, U.K. Ministry of Aviation.

Conference objectives were to establish navigational principles and operational objectives in relation to the navigation of aircraft on long-distance flights and the transition between long-range and short-range environments. In addition, an attempt was made to define the airlines preferences for navigation systems and to collate the results of recent world-wide studies of navigation systems, especially those self-contained.

Navigation principles, capabilities, problems and operational objectives were considered, with special focus on high-density traffic environments, non-critical environments, transition between long-range and short-range aids, and between terminal and enroute areas.

Subsection V recaps studies of navigational error which were interpreted as gaussian distributions versus those non-gaussian (possibly exponential, per Reich).

Papers authored by or sponsored by IATA included the Agenda (WP-1), Annotated Agenda (WP-2), Extracts from Previous IATA and ICAO Reports Concerning Long Distance Navigation (WP-3), and Navigational Ability and Requirements as Determined by the ICAO Special NAT Meeting of March 1965 (WP-116).

See also Journal of the Institute of Navigation, Vol. 18, No. 4 for a report of the 16th IATA Technical Conference. Editorial recapitulation therein of "Errors and Accuracy" contributions at the Conference is particularly germane to the subjects of interest in this bibliographical listing.

IBM-Canada, Ltd. 1971
GAATS: GANDER AUTOMATED AIR TRAFFIC SYSTEM (IBM)

ICAO 1974
METHODOLOGY FOR THE DERIVATION OF SEPARATION MINIMA APPLIED TO THE SPACING BETWEEN PARALLEL TRACKS IN ATS ROUTE STRUCTURES

International Civil Aviation Organization, Montreal, Canada;
Circular 120-AN/89.

This circular is published to facilitate research and development in the field of aircraft separation. It also will assist in evaluating the work progress thus far achieved by the RGCS Panel (Review of the General Concept of Separation Panel) in the derivation of separation minima for the spacing of parallel tracks. The RGCS Panel itself stressed that its results were preliminary, and has invited submission of material suitable for use in its work on separation standards.

In six sections, this publication (1) reviews RGCSP Task 1 progress; (2) describes the model for assessing collision risk in parallel route structures; (3) discusses collection and analysis of data on air navigational accuracy (West European domestic airspace); (4) presents statistical analysis of main data collection in 1972; (5) discusses estimation of P_{xz} (probability of overlap); (6) discusses the use of target level of safety in the assessment of separation values; (7) presents preliminary assessment of the safe separation between the center lines of parallel routes (using model studies). References listed are very precise and limited.

The Air Navigation Commission (ANC), at the Sixth Meeting of the ANC 75th Session, February 1974, recognized both this Circular and the invitation to the States to consider RGCSP recommendations 1/1 and 1/2 (RGCSP Second Meeting, Montreal, October 1973) in establishing parallel tracks in their respective route structures.

ICAO, NAT-SPG September 1969
REPLIES FROM THE NAT SYSTEMS PLANNING GROUP TO THE QUESTIONS POSED BY THE ASTRA PANEL

IATA/ASTRA: Panel on Application of Satellite Techniques Related to Aeronautics; working paper ASTRA-WP/12.

IEEE March 1970
PROCEEDINGS OF THE IEEE: VOLUME 58, No. 3, AIR TRAFFIC CONTROL

Institute of Electrical and Electronics Engineers, New York, New York; special issue on Air Traffic Control.

Institute of Navigation (U.K.) October 1965
THE SIXTEENTH IATA TECHNICAL CONFERENCE

Journal of the Institute of Navigation (U.K.), London, England; Vol. 18, No. 4; feature report article.

The ION editor itemizes the objectives of the IATA 16th Technical Conference (April 22-30, 1965 at Miami), as (1) the nature and magnitude of current navigation problems in high-density traffic, non-critical environments, and transition from long-range to short-range environments; (2) navigational principles and objectives in high-density traffic, non-critical environments, and transition between enroute and terminal concepts; and (3) the capability of existing and advanced navigational aids including self-contained, long-range, short-range and satellite systems. In a recapitulation of "Errors and Accuracy" contributions to the IATA Conference, the ION editor presents an excellent description of the current leading positions on the subject.

Institute of Navigation (U.K.) 1971
THE JOURNAL OF THE INSTITUTE OF NAVIGATION, VOLUME 24, Nos. 1, 2, 3, and 4

The Institute of Navigation (U.K.), London, England.

J. D. Heath: Costs and Benefits of Air Navigation and Control Systems;
E. R. Swanson: Application of OMEGA to Aircraft Navigation and Traffic Control;
G. T. A. May: A Method for Predicting the Number of Near Mid-Air Collisions in a Defined Airspace;
J. V. Inglesby: A Simple Logic of Radar Avoidance Action;
E. J. Dickie: Air Traffic Control and the Needs of the Customer;
W. P. Robinson: Area Navigation;
W. O. Broughton and J. W. McIvor: Development in Airborne Navigation Systems;
E. W. Anderson and D. M. Ellis: Error Distributions in Navigation;
A. White (U.K.-National ATC Services): Air Traffic Control Separation Minima and Navigational Capability:
D. E. LLoyd (RAE): Mathematical Studies in Separation Standards;
C. M. Britland (RAE): A Preliminary Analysis of Navigational Performance Observed at Strumble 1969-1970.

The last three papers cited above are a series under the heading "ATC Separation Standards and Navigation."

No single other source is perhaps so productive of papers relevant to the study and analysis of separation standard theory and development. Quarterly issues numbered 1, 2, 3, and 4, dated January, April, July, and October, respectively, will be found bound together in the annual volume in many technical libraries which are oriented to the subject fields. Not every volume of the British Journal of Navigation (it bears the abbreviated title since 1970) will include "Air Traffic System Separation Standards" papers, Volume 24 selected here as typical is unusually freighted.

See also "NAVIGATION: Journal of the Institute of Navigation (U.S.)" Washington, D.C., a quarterly.

International Information Inc. April 1967
PROJECT DIOSCURES: A SYSTEM OF CONTROL AND AERIAL NAVIGATION FOR SATELLITES

National Aeronautics and Space Administration, Washington, D.C.; NASA-TT-F-10844, translation from French.

David R. Israel (FAA) October 1974
AN OVERVIEW OF THE UPGRADED THIRD GENERATION AIR TRAFFIC CONTROL SYSTEM

IEEE, Institute of Electrical and Electronics Engineers, Inc., New York, N.Y.; paper published in EASCON '74: report of the Electronics and Aerospace Systems Convention, Washington, D.C., October 7-9, 1974.

The air traffic system planned by FAA for FAA use in the 1980's and beyond is a group of subsystems labelled the Upgraded Third Generation ATC System (UG3rd, in FAA internal documentation). Its nine major features are IPC (Intermittant Positive Control), DABS (Discrete-Address Beacon System), RNAV (Area Navigation concept), MLS (Microwave Landing System), ASTC (Airport Surface Traffic Control), WVAS (Wake Vortex Avoidance System), FSS (Flight Service Station modernization/automation), AEROSAT (Aeronautical Satellite service possibly involving navigation, communication, control, and surveillance), and Increased Automation (enhanced ARTS-NAS). An overview authored by a leading management official in FAA System Engineering should be of interest to those concerned with ATC separation standard studies.

C. C. Jackson June 1966
THE SEPARATION OF AIR TRAFFIC OVER THE NORTH ATLANTIC

Flight International (magazine), Vol. 89, pp. 967-70.

Discusses separation of aircraft in the North Atlantic system with particular attention to the proposed reduction of parallel-route lane-width from 120 nautical miles to 90 nautical miles.

J. Jaffe, et al. (NASA) May 1966
FINAL REPORT OF THE AD HOC JOINT NAVIGATION SATELLITE COMMITTEE

National Aeronautics and Space Administration, NASA Headquarters, Washington, D.C.

L. L. Jenny and R. S. Ratner December 1975
MAN AS MANAGER OF AUTOMATED RESOURCES IN AN ADVANCED AIR TRAFFIC SYSTEM

Journal of Aircraft, Vol. 12, No. 12, Paper presented at AIAA Conference on Life Sciences and Systems, Arlington, Texas, Nov. 6-8, 1974.

The DOT ATC Advisory Committee (ATCAC) report of 1969 projected system demand in 1995 to have doubled or tripled. The economic impact of this growth is manifested in many ways; operations and maintenance costs are the major cost element. These costs are primarily the salaries and benefits for controller, flight service, and maintenance personnel.

Automation already implemented will provide a system-wide basis for manpower savings. Enhancement of automated subsystems already under investigation includes PATWAS, TWEB, ATIS, DABS, INS, CAS, AATM, and numerous corollaries.

The "fourth generation ATC System, which is in only a conceptual stage" would use automation to achieve three major benefits: (1) enhanced flight safety, through more complete and accurate navigation and surveillance systems and "through machine-directed separation assurance"; (2) extensive application of computers to promote efficient use of airspace and to expedite traffic flow, via computerized techniques for flow control, terminal area metering and spacing, and close monitoring of flight plan conformance; and (3) decreased dependence on manual operations, and thereby a reduction in the workforce, "and this is perhaps the dominant concern."

The intent of this paper is to speculate about the nature of man's participation in a future ATC system where much of the routine operation has been delegated to machine resources, and in particular to examine the implications of automation for man as operator and manager of such a system. Authors Jenny (The Planar Corp.) and Ratner (Stanford Research Institute) participated in the ATCAC report study, but herein depart on an original discussion not summarizing ATCAC study results but speculating on developments they imply.

While not addressing separation specifics such as mathematical models and algorithms, relates considerations of separation (including what machine subsystems and operational techniques will apply) to system design and management considerations.

Richard S. Jensen and Stanley N. Roscoe (Univ. of Illinois) June 1973
A FLIGHT EVALUATION OF PILOTAGE ERROR IN AREA NAVIGATION WITH VERTICAL GUIDANCE

Institute of Navigation (U.S.), Washington, D.C.; Proceedings of the 29th Annual Meeting of the ION, St. Louis, Missouri; June 1973.

The following document is closely related.

Richard S. Jensen and Stanley N. Roscoe (Univ. of Illinois) August 1974
FLIGHT TESTS OF PILOTAGE ERROR IN AREA NAVIGATION WITH VERTICAL GUIDANCE

University of Illinois, Champaign, Illinois; Technical Report No. FAA-RD-74-148, under Contract DOT-FA71WA-2574 for FAA, SRDS.

Pilotage error was measured from flights on a three-dimensional procedure using "simplified" area navigation. Variables included vertical display type, pilot experience, angle of climb or descent. Pilot performance measures were vertical and horizontal steering, airspeed control, and procedural errors. Pilotage error results were compared statistically with corresponding values from previous studies or previously assumed by FAA (AC 90-45) and RTCA (DO-152). Portions which discuss vertical and horizontal errors are related to our interest in separation standards; the main focus of this study on human factors relates rather to pilot/controller performance measurement programs currently ongoing in FAA.

February 1962
A. B. Johnson, N. A. Houska, P. J. O'Brien, L. N. Douglass, Jr, P. W. Bradbury, and J. F. Horvath
EVALUATION AND DYNAMIC SIMULATION STUDY OF THE ROME, ITALY, TERMINAL AREA

Federal Aviation Administration, National Aviation Facilities Experimental Center, Atlantic City, New Jersey.

The FAA/ARDS/Evaluation Division conducted a dynamic simulation study for the Italian Air Force and Air Traffic Control Service concerning the Rome Terminal Airports Complex. A procedural solution was developed to segregation of civil traffic at the major international airport from high-speed military fighter traffic from an adjacent airport sharing the same airspace. Typifies a separation study by simulation modelling rather than by mathematical modelling or analysis.

John R. Juroshek (Institute for Telecommunication Sciences) February 1975
PROBABILISTIC INTERFERENCE PREDICTION MODEL: COMPUTER PROGRAMS

Federal Aviation Administration, Systems Research and Development Service, Washington, D. C., FAA-RD-75-33; by the Institute of Telecommunication Sciences (U.S. Dept. of Commerce, Boulder, Colorado) under Contract DOT-FA74WA-I-441.

Describes a statistical method for predicting interference between air traffic control frequency assignments in the VHF frequency band for aeronautical mobile use. Two computer programs are described for computing probability of interference; one uses Monte Carlo methods, the other is deterministic.

Simon Justman (FAA) June 1961
SEPARATION CRITERIA AND DECISION PROCESSES

Federal Aviation Administration, Research Division, National Aviation Facilities Experimental Center, Atlantic City, New Jersey.
Project Note No. 61-3, "Enroute Aircraft Separation Criteria" project.

S. L. Katten November 1968
AIR TRAFFIC CONTROL TRUTH AND CONSEQUENCES

The Rand Corporation, Santa Monica, California.

Discusses the system concept, historical background, the current air traffic control system, air transportation system problems, and air traffic control problems. Identifies some probable causes, some objectives to alleviate the problems described, and also identifies alternative consequences.

Myron Kayton (TRW Systems Group) and Walter R. Fried (AUTONETICS) 1969
AVIONICS NAVIGATION SYSTEMS

John Wiley & Sons, Inc., New York; hardbound.

A unified treatment by 14 distinguished contributors of the principles and practices of modern aircraft navigation systems and the burgeoning technology, "avionics". For the navigation system engineer, whether user or designer; also serves system analyst who writes mathematical models, as well as operations personnel who encounter new "black boxes" proliferating in aircraft equipment systems. Discusses state-of-the-art, as well as fundamental principles and basic functions of each system.

F. S. Keblawi and A. P. Smith July 1974
AN ANNOTATED BIBLIOGRAPHY OF LITERATURE RELATED TO OCEANIC ATC COLLISION SAFETY AND COST/BENEFITS

The MITRE Corporation, McLean, Virginia; MITRE Technical Report MTR-6720; for Federal Aviation Administration.

A comprehensive listing of papers concerned with collision risk, safety assurance, and cost/benefits of oceanic ATC route structures and related topics. Many of the documents listed may be of interest to those studying non-oceanic routes, ATC procedures, or separation standards.

The contents are organized into two categories: (1) safety-related literature, and (2) literature on cost-penalty associated with separation standards, for both subsonic and supersonic flights. Cross-indexing is applied to documents which suit both categories.

For safety-related literature, three categories are identified: (a) those based on "Probabilistic" models, (b) those which are "Deterministic," and (c) "Related" papers of other topical scope.

While attention has been paid to inclusion of items selected from MTR-6720 in this listing, the user is advised to go directly to MTR-6720 to benefit from its "Introduction" and perceptive "sorting" on "Probabilistic" versus "Deterministic" lines.

F. S. Keblaw, M. J. Spahn (MITRE) August 1976
IMPACT OF RADAR DATA PROCESSING ON CONTROLLER PRODUCTIVITY

The MITRE Corporation, McLean, Virginia; Technical Report No. M76-55.

Radar data processing by computer to translate and display aircraft position information is a feature of the NAS enroute ATC system. The impact of the radar data processing feature on the productivity of enroute ATC controller teams is evaluated in this report on the basis of data collected at Air Route Traffic Control Centers at Los Angeles, Indianapolis, and Miami. Five ways of viewing the data without regard to the sample size or the quality of the measure were suggested by the FAA Air Traffic Service. The authors present the result figure for each of these viewpoints. However, the bulk of this 22-page summary report considers a sixth viewpoint which uses the peak aircraft figure as the most reliable of the measures and applies certain weighting factors to reflect the quality of the measure. Data is presented in eight tabular or plotted summaries. Discussion is limited to 10 pages of evaluatory or concluding comment.

A. R. Kerstein (Princeton University) April 1974
ANALYSIS OF THE REICH MODEL FOR AIRCRAFT COLLISION RISK

Published by Princeton University, Princeton, N.J., prepared for the FAA Systems Research and Development Service.

The Reich model for aircraft collision risk is recast into a form which clearly exhibits its conceptual framework. Analytical and numerical sensitivity analyses indicate the relative importance of the twelve independent variables in the collision risk equations. Proposals for implementation of a risk analysis are made in light of previous efforts, with emphasis on procedures for modeling the distribution of large track-keeping errors.

N. J. Kirkendall (MITRE) August 1975
REVIEW OF THE WORKING PAPERS OF WORKING GROUP "C" OF THE RGCSP ON LATERAL SEPARATION STANDARDS IN EUROPEAN EN ROUTE AREAS

The MITRE Corporation, McLean, Virginia; MITRE Technical Report No. MTR-6882.

This report summarizes and discusses the work of Working Group "C" of the ICAO panel for Review of the General Concept of Separation (RGCSP). The primary thrust of Working Group "C" work has been the evaluation of lateral separation standards for parallel routes in en route areas when radar is not used for control purposes. This evaluation has been performed via a collision-risk analysis with data collected in France, and with data concerning estimated traffic densities on the busy routes in Europe. The text addresses lateral separation based on navigation alone without surveillance, and on navigation with surveillance, and comments on target levels of safety, the collision risk model, and the background of the RGCSP and its working groups.

N. J. Kirkendall (MITRE) April 1976
A REVIEW OF RGCSP WORK ON THE DETERMINATION OF LATERAL SEPARATION STANDARDS

The MITRE Corporation, McLean, Virginia; MITRE Report No. M76-8.

The text and Appendix B of this paper respectively are two papers prepared by the author for presentation to the Ninth Air Navigation Conference in 1976. The text addresses lateral separation between parallel routes, target levels of safety, the collision risk model, and data on lateral deviations and lateral speeds. The Appendices A and B discuss the work program of the ICAO RGCSP (Review of the General Concept of Separation Panel) and the requirements for additional work by the RGCSP.

Stanley A. Klein July 1973
STUDY OF OCEANIC AIRSPACE AND GROUND NETWORK CONFIGURATIONS IN SATELLITE SYSTEMS

Computer Sciences Corporation, Falls Church, Va., Final Report FAA-RD-73-59.

J. F. Koetsch (NAFEC) April 1961
A THREE-DIMENSIONAL MATHEMATICAL MODEL OF THE AIR TRAFFIC CONTROL SEPARATION PROBLEM

Federal Aviation Administration, Aviation Research and Development Service, NAFEC, Atlantic City, New Jersey; published by NAFEC in Proceedings of the First Annual International Aviation Research and Development Symposium.

J. F. Kolnick and B. S. Bently July 1963
RANDOM DEVIATIONS FROM STABILIZED CRUISE ALTITUDES OF COMMERCIAL TRANSPORTS AT ALTITUDES UP TO 40,000 FEET WITH AUTOPILOT IN ALTITUDE HOLD

National Aeronautics and Space Administration, Washington, D.C.; Technical Note NASA-TND-1950.

J. F. Kolnick and B. S. Bentley January 1966
REPORT ON THE VERTICAL SEPARATION STUDY, NORTH ATLANTIC REGION-JULY 15 to SEPTEMBER 30, 1963

Journal of the Institute of Navigation (U.K.), London, England; Volume 19, No. 1.

Also published earlier by International Air Transport Association as IATA Document General No. 1951.

June 1974

Nestor B. Kowalsky, Richard L. Masters, Richard B. Stone, Gary L. Babcock, and Eugene W. Rypka

AN ANALYSIS OF PILOT-ERROR RELATED AIRCRAFT ACCIDENTS

National Aeronautics and Space Administration, Washington, D.C.; by Lovelace Foundation, Albuquerque, New Mexico, for NASA, contract report NASA-CR-2444.

Applies cluster analysis as a means of attacking an otherwise unmanageable large set of data in matrix form. Uses a multi-disciplinary approach to reclaim hidden human error information not shown in statistical studies from pilot-error related accident investigation records. Among the "new analytic techniques ... applied," three techniques of analysis were (1) critical element analysis, (2) cluster analysis, and (3) pattern recognition.

Lear-Siegler Corp. June 1966
OMEGA, A WORLDWIDE RADIO NAVIGATION SYSTEM

Lear-Siegler Corporation, Grand Rapids, Michigan; in company descriptive literature, Lear-Siegler document number GR-66-1176.

Jerome Lederer and P. Rosenberg February 1967
PROCEEDINGS OF THE ION NATIONAL AIR MEETING ON COLLISION AVOIDANCE
Institute of Navigation (U.S.), Washington, D.C.

Homer Q. Lee, Frank Newman, and Gordon H. Hardy August 1975
4D AREA NAVIGATION SYSTEM DESCRIPTION AND FLIGHT TEST RESULTS

National Aeronautics and Space Administration, Ames Research Center, Moffett Field, California; Technical Note No. NASA-TND-7874.

A 4D area navigation system was designed to guide aircraft along a prespecified flight path (reference path) such that the aircraft would arrive at the approach gate at a time specified by the ATC controller.

Describes how a system designed for automated guidance in four dimensions to terminal approach by STOL (Short Take-Off or Landing) aircraft was tested at Ames Research Center in manual mode using a CV-340 CTOL (Convair 340 Conventional Take-Off or Landing) aircraft. Of interest is the Executive Algorithm.

V. M. Leshchenko 1966
ALGORITHMIZATION OF THE PROCESSES OF CONTROL OF AIR TRAFFIC

National Aeronautics and Space Administration, Washington, D.C.; NASA Technical Note NASA-TN66-24531.

Simon F. Lister and Gordon Raisbeck (Arthur D. Little, Inc.) May 1971
AN APPROACH TO THE ESTABLISHMENT OF PRACTICAL AIR TRAFFIC CONTROL SAFETY GOALS

Arthur D. Little, Inc., Cambridge, Mass.; for FAA Systems Research and Development Service, Washington, D.C.; Report No. FAA-RD-71-36.

Examines the improvement in over-all air transportation safety which could be achieved by reducing all sources of accident which are in any way related to air traffic control. The method combines the incidence of fatal aircraft accidents with an estimate of the over-all risk in various types of human activity. Ultimately the technique leads to identification of a set of mutually compatible risk goals for each of 36 risk groups. This measure enables managerial analytic development of such conclusions as reductions in risk (of specified character) "only if sources of risk totally outside of air traffic control are substantially reduced....".

This report shows how rational, quantitative goals for the risk associated with air traffic control can be produced by combining accident-incidence rate and cause data with an estimate of overall risk in various types of human activity.

Arthur D. Little, Inc. October 1970
A STUDY OF AIR TRAFFIC CONTROL SYSTEM CAPACITY

Arthur D. Little, Inc., Cambridge, Mass.; for the Federal Aviation Administration under Contract FA70WA-2141.

Joseph W. Little (University of Michigan) April 1965
AIRCRAFT SEPARATION CRITERIA FOR THE SST

Journal of the Institute of Navigation (U.K.), London, England; Volume 18, No. 2; also published in AIRCRAFT NAVIGATION: THE 16th IATA TECHNICAL CONFERENCE (Montreal, April 1965) by the International Air Transport Association (Montreal).

Discusses nonradar separation criteria applicable to the supersonic transport. Analyzes equations which show the factors that influence separation. Makes suggestions for a supersonic air traffic control system for the North Atlantic. It is shown that the longitudinal separation in time, but not the lateral separation, may be substantially less than for subsonic jet aircraft.

D. E. Lloyd (RAE) May 1967
CAN SIGHTING REPORTS INDICATE COLLISION RISK OVER THE NORTH ATLANTIC?

Royal Aircraft Establishment, Farnborough, England; RAE Technical Report 67122.

D. E. Lloyd (RAE) October 1971
MATHEMATICAL STUDIES ON SEPARATION STANDARDS

Journal of Navigation (U.K.), London, England; Vol. 24, No. 4, pp. 456-458.

Second of a series of three papers in this issue entitled "Air Traffic Control Separation Standards and Navigation." Describes briefly the mathematical theory of collision risk for parallel tracks. Part of a programmed work of the Mathematics Department at RAE concerned with methods of estimating the collision risk procedural systems. Tables the 1967 calculated results of required centre-line spacing between air routes. Relates navigation standards to separation standards by way of their effect on collision risk.

D. E. Lloyd (RAE) September 1972
THE SPECIFICATION OF NAVIGATIONAL CAPABILITY IN RELATION TO NORTH ATLANTIC SEPARATION STANDARDS

Royal Aircraft Establishment, Farnborough, England; RAE Technical Report 72175; Departmental Reference, Math 207.

Investigates the relationship between the required lateral separation standard and the specification of navigational capability. Accuracy and reliability requirements for navigational equipment are derived; collision risks are compared for two possible types of SST track structure. Subsonic and supersonic aircraft are considered.

D. E. Lloyd (RAE) October 1972
STUDIES OF SYSTEM TRACK-KEEPING ACCURACY AND SPACING OF TWIN-TRACK AIRWAYS

International Air Transport Association, Montreal, Canada; paper presented at the 19th IATA TECHNICAL CONFERENCE (Dublin Oct. 23-28, 1972), Working Paper WP-45.

Safe separation between opposite-direction twin-track airways is considered, using simple models of two possible types of traffic control system. This preliminary analysis suggests that, when a reasonably precise navigational system becomes available, radar surveillance of opposing traffic streams may not lead to a worthwhile reduction in the track separation needed for an acceptable level of safety. It may be preferable to use the radar in an "offline" role, to record large deviations from nominal track for later investigation. The data and methodology of a more adequate analysis are discussed.

D. E. Lloyd and P. P. Scott (RAE) June 1973
APPLICATION OF MONTE CARLO METHODS TO ESTIMATION OF COLLISION RISKS ASSOCIATED WITH ATC SEPARATION STANDARDS

Royal Aircraft Establishment, Farnborough, England; RAE Technical Report 73104.

R. G. Loeliger February 1974
CONCEPT FOR A SATELLITE-BASED ADVANCED AIR TRAFFIC MANAGEMENT SYSTEM, VOL. II: SYSTEM FUNCTIONAL DESCRIPTION AND SYSTEM SPECIFICATION

AUTONETICS, North American Rockwell Corporation, Anaheim, California; for Department of Transportation Systems Center Cambridge, Mass.; Technical Report No. DOT-TSC-73-29, II

See same title "authored by" AUTONETICS.

R. N. Lord and D. A. Saunders December 1964
A MATHEMATICAL DERIVATION OF AIR TRAFFIC CONTROL SEPARATION STANDARDS

College of Aeronautics, Cranfield, England; Report E&C No. 5, 33 pages.

Presents a mathematical derivation of lateral and longitudinal separation standards in Air Traffic Control.

R. N. Lord (U.K.; College of Aeronautics, Cranfield) April 1965
PROPOSALS FOR THE MATHEMATICAL FORMULATION OF SEPARATION STANDARDS

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th TECHNICAL CONFERENCE (Miami, April 22-30, 1965) Working Paper WP-16; also published (modified title) in Journal of the Institute of Navigation (U.K.), Volume 18, No. 4.

ATC is considered a feedback system dependent on intermittant positional information being supplied to the ground facility for control services. Considers the mathematical model of the enroute phase of a long flight over unpopulated (sea) areas, after outlining the basis for developing ATC criteria, and considering basic errors in navigation.

Gives a mathematical formulation of lateral and longitudinal separation standards for subsonic and supersonic aircraft operation.

R. N. Lord (U.K.; College of Aeronautics, Cranfield) April 1965
THE MATHEMATICAL FORMULATION OF SEPARATION STANDARDS

Journal of the Institute of Navigation (U.K.) London, England; Volume 18, No.4., also published by the International Air Transport Association, Montreal, in AIRCRAFT NAVIGATION: THE 16th IATA TECHNICAL CONFERENCE (Miami, April 1965).

A mathematical approach to Air Traffic Control separation criteria indicates that a more economic use could be made of the available airspace. Reduction of longitudinal separation would be possible with more frequent reporting of aircraft position. As aircraft speeds increase in the future, more attention will be required to speed control and heading accuracy.

R. N. Lord (U.K.; College of Aeronautics, Cranfield) April 1966
SEPARATION STANDARDS AND AIRCRAFT WANDER

Journal of the Institute of Navigation (U.K.), London, England;
Vol. 19, No. 2, pp. 198-208.

Statistically combines the basic parameters leading to aircraft navigational error, and uses them to estimate the uncorrected track deviation (wander) to be expected. Presents graphically the variation of size of the ATC block of protective airspace. Demonstrates the effect of improved control of the along-track and across-track wander. Thus establishes that, in future, more attention must be directed to improvement of heading accuracy and speed control.

Robert E. Machol (Northwestern Univ.) Revised July 1974
NAVIGATION STANDARDS OVER THE NORTH ATLANTIC (see also April 1974)

Paper presented at the Joint Meeting of the Institute of Management Sciences with the Operations Research Society of America, Boston, Mass., April 22, 1974.

Discusses the 1964 controversy between operating pilots of the airlines and the proposal by the U.S. FAA (through ICAO) to reduce lateral separation between tracks (routes) in the North Atlantic from 120 nmi to 90 nmi. Describes the problem, the controversy, the model, the data collection and reduction, the solution, and the implementation.

The fluid narrative style of this state-of-the-art authority makes this excellent basic reading; it can easily be read, rather than studied.

Appeared under title as above in INTERFACES (February 1975) as "the prize winning award paper." Also published by the Institute of Management Sciences in MANAGEMENT SCIENCE, Vol. 21, No. 10, June 1975 under the title "An Aircraft Collision Model."

Robert E. Machol (Northwestern University) June 1975
AN AIRCRAFT COLLISION MODEL

Management Science, Vol. 21, No. 10, pages 1089-1101; Paper presented at the Joint Meeting of the Operations Research Society of America (ORSA) and the Institute of Management Sciences (IMS) Boston, April 22, 1974, under the title Navigation Standards Over the North Atlantic, (and so indexed in this listing).

In the 1960's a controversy arose regarding the safety of navigation standards of jet aircraft over the North Atlantic Ocean, which led to a confrontation between airline owners and pilots. A systems analysis led to a redesigned and improved system which resolved the controversy by giving each side at least as much as it originally requested, in terms of minimizing cost on the one hand and maximizing safety on the other. This paper describes the problem, the controversy, the model, the data collection and reduction, the solution, and the implementations. 5 references.

Bertrand Manuali April 1969
THE DIOSCURES PROJECT

Journal of the Institute of Navigation (U.K.), London, England; Vol. 22, pp. 172-183, April 1969; also published in L'Aeronautique et l'Astranautique, No. 22, pp. 13-19, 1970; European Navigation Institutes, Quadripartite Meeting, Rome, Italy, May 11-14, 1970; Ingegneria January 1972; and ITU Telecommunication Journal, Vol. 36, pp. 79-87, February 1969.

Description and discussion of the French Dioscures Project designed to ensure air (and ship) traffic safety over the Atlantic and Pacific oceans with the aid of a network of geostationary satellites.

See also "Dioscures" items by Villiers, deBarbeyrac, and Baudry.

Bertrand Manuali (National Center of Space Studies, France) July 1971
PERSPECTIVES OF USE AND DEVELOPMENT OF SATELLITES FOR AVIATION AND THE MERCHANT MARINE

In NAVIGATION (periodical), Paris, France, Volume 19, pp. 299-315. In French.

Assesses the portion of total needs of civil aviation and the merchant marine for communication and position location which could effectively be met by a satellite system. Defines the essential characteristics of such a satellite system. In addition, discusses antennae and communication channel requirements. Discusses the proposed three-satellite system for the Atlantic-Pacific. Speculates on the economic and technical potentialities of a first satellite generation.

B. L. Marks (RAE) February 1963
AIR TRAFFIC CONTROL SEPARATION STANDARDS AND COLLISION RISK

Royal Aircraft Establishment, Farnborough, England; RAE Technical Note Math 91, 93 pages.

The consideration of safety in an air traffic control system is divided into two parts. The first part is concerned with the over-all amount of proximity between pairs of aircraft which is planned or inherent in the system. It is shown how this may be analyzed and displayed by using mathematical models, by simulation on a digital computer, and by processing retrospective-flight data.

The second part is concerned with the risk of collision produced by proximity. This is a problem of gathering knowledge about very large errors in following a flight plan. A study is made of the amount of data that would be required to give worthwhile numerical estimates. Techniques are demonstrated for the calculation of collision probabilities from such data.

Dr. Gene R. Marner (Collins Radio) Winter 1970-71
CONCEPTUAL QUESTIONS IN AIR TRAFFIC CONTROL DESIGN

Journal of the Institute of Navigation (U.S.), Washington, D.C.; in AIRCRAFT NAVIGATION: Vol. 17, No. 4, also published by Institute of Navigation in Proceedings of the National Air Meeting on Air Traffic Control in the 1970's, St. Louis, Mo., April 14-16, 1970, pp.11-18.

Dr. Marner analyzes ATC system safety, capacity and delay in this "very general, almost philosphical discussion." Considers terminal operations, runway capacity, and aircraft spacing.

Recommended for attention because of its subject matter, its author, and its efficient list of readings.

G. T. A. May April 1971
A METHOD FOR PREDICTING THE NUMBER OF NEAR MID-AIR COLLISIONS IN A DEFINED AIRSPACE

Journal of Navigation (U.K), London, England; Vol. 24, No. 2, pp. 204ff.

The development of routing and control procedures should take into account the degree of risk associated with any particular route structure. In the case of near mid-air collisions (NMAC's) or collisions, quantitative prediction of the risk involved is difficult. In this paper, a simple theoretical method for predicting the number of NMAC's for a particular route structure is given. Such a method has been used for determining the amount of control required for a particular off-airways area and to help determine the optimum control procedures for that area.

J. S. May August 1966
AN ANALYSIS OF THE NORTH ATLANTIC PRINCIPAL AREA SEPARATION STANDARDS AND COMMUNICATIONS PROBLEMS FOR THE TIME PERIOD FROM THE PRESENT TO 1980

Federal Aviation Administration working paper for Project 221-160-01C

J. A. Maynard Winter 1971-1972
AIRCRAFT COLLISION PREVENTION IN HIGHLY DENSE ENVIRONMENTS

NAVIGATION: Journal of the Institute of Navigation (U.S.), Washington, D.C.; Vol. 18, No. 4, pp. 409-416.

Reviews statistics that describe the problem of the increasing probability of midair collisions in the present aviation environment. Discusses efforts directed at a solution of this problem. Presents an example of a solution reached in the case of a special situation. Suggests a plan for the development of a total solution.

Keith D. McDonald Winter 1973-1974
A SURVEY OF SATELLITE-BASED SYSTEMS FOR NAVIGATION, POSITION SURVEILLANCE, TRAFFIC CONTROL, AND COLLISION AVOIDANCE

NAVIGATION: Journal of the Institute of Navigation (U.S.), Washington, D.C.; Vol. 20 No. 4.

Keith D. McDonald (FAA) July 1975
THE SATELLITE AS AN AID TO AIR TRAFFIC CONTROL

Radio Technical Commission for Aeronautics, Special Committee 62; technical document number RTCA-DO-63 (May 3, 1975); also published in AGARDograph AG-209-Vol. II (July 1975) by NATO/Advisory Group for Aerospace Research and Development, Neuilly-sur-Seine, France.

A reevaluation of VOR Airway Lateral Separation Criteria; also a reevaluation of enroute ascending, descending, and passing procedures. The Appendixes contain the results of flight and laboratory tests and statistical analyses of the bearing errors of VOR facilities and of airborne VOR receivers.

A. W. Merz July 1975
APPLICATION OF DIFFERENTIAL GAME THEORY TO ROLE-DETERMINATION IN AERIAL COMBAT

Aerophysics Research Corp., Bellevue, Washington, for National Aeronautics and Space Administration; contract report No. NASA-CR-137713.

Discusses the development of criteria which specify the roles of pursuer and evader as functions of the relative geometry and of the important parameters of the problem. A reduced-order model of the relative motion is derived and discussed. In this model, the two aircraft move in the same plane at unequal but constant speeds, and with different maximum turn rates. The equations of relative motion are of third order, the dependent variables being the relative range, bearing, and heading of the two aircraft. Termination of the pursuit-evasion game is defined by either the heading-limited or the range-limited end condition. These are geometric conditions for which the evading aircraft is in front of the other, with the relative heading and relative range satisfying certain inequalities. Retrograde solutions to the equations of relative motion were used with the derived optimal terminal maneuvers to find where an assumed set of end conditions could have begun.

George E. Meyer (Air Force Weapons Lab.) March 1975
THE APPLICATION OF PROBABILITY CALCULATIONS FOR BIRD-AIRCRAFT STRIKE ANALYSES AND PREDICTIONS USING RADAR

Air Force Weapons Lab., Kirtland AFB, New Mexico; technical report No. AFWL-TR-74-145.

A theoretical development for the calculation of binomial probability distribution functions for assessing the risk of bird hazards to aircraft by means of radar. A set of airspace cells is defined by beam geometry and pulse width and a given aircraft flight path, each with a determined number of birds. Each distribution function can be studied to determine the maximum risk and the corresponding number of birds involved. The cumulative probability of bird strikes over an entire route can be determined by calculating the union of discrete cell probability sets.

D. J. Mohr January 1973
AIRCRAFT TRANSITION ALGORITHM FOR CONFLICT PREDICTION: WITH SPECIFIC REFERENCE TO THE NORTH ATLANTIC AIR TRAFFIC CONTROL SYSTEM

University of Toronto (Canada), Institute for Aerospace Studies (UTIAS), Technical Note UTIAS TN-183.

To fulfill the specific needs of the Gander (Newfoundland) automated air traffic control system, a simulation algorithm was designed to search out, detect, and resolve conflict situations during enroute aircraft transitioning; and ATC conflict-prediction simulation models were developed for digital, fast-time simulations.

The results either are applicable to (possibly any) "strategically controlled environment" of multiple aircraft airspace, or are directly illuminating in the development of such systems. The simulation model includes route structure, flight trajectory construction, meteorological data, and a conflict resolution option.

R. R. Monk and M. May February 1965
DIFFERENCES IN TRANSATLANTIC FLIGHT TIMES TAKEN BY PAIRS OF CIVIL JET AIRCRAFT ON PROXIMATE PATHS

A.O.R.B., Operations Research Note No. 189, February 1965.

Alton B. Moody (FAA) April 1965
THE ROLE OF SATELLITES IN AIR NAVIGATION

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE, (Miami); Working Paper WP-91.

Discusses the potential value of a common satellite system. The navigational value of satellites would seem to be greatest in connection with ground stations, and as a communications link allowing more effective and perhaps simpler, airborne equipment, a more complete world coverage and an emergency warning system.

Capt. Alton B. Moody (USNR) Spring 1969
THE NATIONAL PLAN FOR NAVIGATION

NAVIGATION: Journal of the Institute of Navigation (U.S.), Washington, D.C.; Vol. 16, No. 1.

R. E. Moir and H. D. Most 1969
A SUMMARY OF THE COMPUTER SIZING PORTION OF THE GROUND-BASED COLLISION AVOIDANCE FUNCTION FOR THE 1980-1990 AIR TRAFFIC CONTROL SYSTEM

ARIES Corporation, Contract DAH004-69-C-0025.

J. S. Morrel 1956
FUNDAMENTAL PHYSICS OF THE AIRCRAFT COLLISION PROBLEM

Bendix Aviation Corp., Tech. Memo. 465-1016-39.

W. W. Moss (Pan American World Airways) May 1969
THE APPLICATION OF SELF-CONTAINED NAVIGATION SYSTEMS IN WORLDWIDE LONG RANGE NAVIGATION

Canadian Aeronautics and Space Institute, Ottawa; Canadian Aerospace and Space Journal, Ontario, Canada, Vol. 15.

Paper presented on Nov. 26, 1968 at the International Aerospace Exposition held in Montreal. Includes recapitulation of navigational milestones, 1962-1968; esp. FAA/Litton/PanAm, Boeing-AC Electronics-PanAm.

The summarized thesis of this article is that air traffic control separation standards "could be safely reduced to 90 nmi for Doppler/computer equipped aircraft, and to 45 nmi for inertial equipped aircraft" based on comparison of their respective navigational accuracies demonstrated in the North Atlantic. Introduction of B747 equipped with Carousel IV inertial system "appears to be a breakthrough for a transition to reduced transition standards."

A. S. L. Nagy March 1968
OPERATIONAL ANALYSIS OF TIME-FREQUENCY COLLISION AVOIDANCE SYSTEMS

Boeing Co., Boeing Document No. D6-19535

B. W. Oakley October 1964
CONFLICT DETECTION AND RESOLUTION IN AIR TRAFFIC CONTROL

Journal of the Institute of Navigation (U.K.) London, England; Vol. 17, No. 4.

Amadeo R. Odoni (MIT) December 1969
AN ANALYTICAL INVESTIGATION OF AIR TRAFFIC IN THE VICINITY OF TERMINAL AREAS

Massachusetts Institute of Technology, Cambridge, Mass.; MIT Operations Research Center Technical Report No. 46.

Amadeo R. Odoni (MIT) May 1971
MODELLING FOR AIR TRAFFIC CONTROL SYSTEMS (BIBLIOGRAPHY)

Massachusetts Institute of Technology, Cambridge, Mass.; MIT (Flight Technical Lab.) paper for presentation at the Operations Research Society of America Conference, Dallas, Texas; MIT FTL Technical Memo No. 71-4.

Our preference above other bibliographies of the subject which we have thus far encountered. Lists 149 titles in alphabetical sequence by author, plus 23 pages of perceptive comment. Categorizes all items by letter codes (G,R,T,E,S,C, or O) meaning models of ground traffic, of runway/final approach traffic, of terminal area traffic, of enroute traffic, safety-related models, cost-oriented models, and other models.

T. B. Parker November 1958
THE EFFECT OF BLUNDERS ON COLLISION RISK CALCULATIONS

Journal of the Institute of Navigation (U.K.), London, England:
Vol. 11, No. 4.

T. B. Parker November 1959
THE CHANCES OF OBTAINING LARGE ERRORS

Journal of the Institute of Navigation (U.K.), London, England;
Vol. 12, No. 4.

B. A. M Piggott February 1965
A NON-LINEAR MAXIMIZATION PROBLEM ARISING IN THE STUDY OF AIRCRAFT COLLISION RISKS

Royal Aircraft Establishment, Farnborough, England;
RAE Technical Report 65044

B. A. M. Piggott August 1967
ATMOSPHERIC TURBULENCE AND AIRCRAFT HEIGHT-KEEPING ACCURACY

Royal Aircraft Establishment, Farnborough, England;
RAE Technical Report 67195

Major W. L. Polhemus, USAF (Retired) January 1965
NAVIGATION SYSTEM REQUIREMENTS FOR SUPERSONIC TRANSPORT

Journal of the Institute of Navigation (U.K.), London, England;
Vol. 18, No. 1.

A. Pool and Th. J. Burgerhout (NLR-Netherlands) May 1964
A FEW NOTES ON THE DETERMINATION OF ACCEPTABLE VALUES FOR THE VERTICAL SEPARATION BETWEEN CRUISING LEVELS OF COMMERCIAL AIRCRAFT

National Lucht-En Ruimtevaartlaboratorium, Amsterdam, Netherlands;
NLR (Netherlands) Report V-1920.

A. Pool and Th. J. Burgerhout (NLR-Netherlands) September 1964
VERTICAL SEPARATION OF CIVIL AIRCRAFT DURING CRUISING

National Lucht-En Ruimtevaartlaboratorium, Amsterdam, Netherlands;
NLR (Netherlands) Report V-1930.

A. Pool and J. L. Simons August 1973
RESULTS OF CALCULATIONS FOR MONITORING THE SAFETY OF THE LATERAL SEPARATION IN THE NORTH ATLANTIC MAIN AREA FOR THE PERIOD 1973-1977

National Lucht-En Ruimtevaartlaboratorium, Amsterdam, Netherlands; NLR (Netherlands) Technical Report TR-73057-U.

PRE November 1963
HEIGHT KEEPING IN LOW-LEVEL CROSS-CHANNEL AIRCRAFT AND ITS INFLUENCE ON PROBABILITY OF COLLISION

Memorandum No. 2007.

G. Raisbeck, B. O. Koopman, S. F. Lister, and A. S. Kapadia October 1970
A STUDY OF AIR TRAFFIC CONTROL SYSTEM CAPACITY

Arthur D. Little, Inc., Cambridge, Mass.; Report No. FAA-RD-70-70.

Describes the functions of the present ATC system, with minimum detailing of equipment or methods which implement the functions. Several approaches to the quantitative use of measures of safety as system variables have been formulated. The mathematical theory of time-dependent queues is found to be applicable to ATC system-capacity problems. Part of the report discusses aircraft-to-aircraft separation.

Gordon Raisbeck October 1971
PROBLEMS IN THE ESTABLISHMENT OF PRACTICAL SAFETY GOALS IN TRANSPORTATION

Arthur D. Little, Inc., Cambridge Mass.; JCSS Conference on Earthquake Risk.

Gordon Raisbeck November 1971
FACTORS INFLUENCING CAPACITY AND EFFICIENCY IN AIR TRAFFIC CONTROL

Arthur D. Little, Inc., Cambridge, Mass.; Report No. FAA-RD-71-107, under Contract No. FA70WA-2141, for Federal Aviation Administration Systems Research and Development Service.

Part of this report discusses factors related to mid-air collisions.

J. L. Ramsey Winter 1973-1974
EFFECTIVENESS LIMITATIONS OF MID-AIR COLLISION AVOIDANCE STRATEGIES

NAVIGATION: Journal of Navigation (U.S.), Washington, D.C.; Volume 20, No. 4.

S. Ratcliffe October 1963
AIRBORNE COLLISION DEVICES COMPATIBLE WITH ATC

Institute of Electrical and Electronics Engineers, Inc., New York, New York; IEEE Symposium on Electronics R&D for Civil Aviation, London.

S. Ratcliffe 1967
AIRCRAFT SEQUENCING, PARALLEL LANDINGS AND THE TMA ROUTE STRUCTURE

National Aeronautics and Space Administration, Washington, D.C.; NASA No. A68-24642.

Paper presented at the IATA Technical Conference, Lucerne, in 1967, and probably also available in a publication of the International Air Transport Association.

S. Ratcliffe (Royal Radar Establishment) October 1971
THE POTENTIAL OF EXISTING AVIONICS TECHNOLOGY

Journal of Navigation (U.K.), London, England;
Volume 24, No. 4, pp. 469-483

Shows those areas in which improved avionics in the relatively near future could contribute to overcoming the limitations described by Reich and Dickie. Direct and efficient in an understandable presentation of the potentials of avionics toward the problem areas of track-keeping, spacing and separation, and collision risk. Very briefly considers the role of ATC, which the author cites from the source (ATA) as supplemented by avionics developments, not supplanted thereby. Cites 21 references worthy of attention.

R. S. Ratner July 1970
A METHODOLOGY FOR EVALUATING THE CAPACITY OF AIR TRAFFIC CONTROL SYSTEMS

Stanford Research Institute Project 8181, First Year-End Report, Volumes I and II.

RCA December 1967
PHASE-DIFFERENCE NAVIGATION SATELLITE STUDY

Radio Corporation of America, Moorestown, N.J., for National Aeronautics and Space Administration, Washington, D.C.; NASA Contractor's Report No. NASA-CR-86028.

RCA December 1968
NAVIGATION/TRAFFIC CONTROL SATELLITE MISSION STUDY

Radio Corporation of America, Moorestown, N.J., for National Aeronautics and Space Administration, Washington, D.C.; NASA Contractor's Report No. NASA-CR-86162.

R. H. Reck (MITRE) December 1972
A NORTH ATLANTIC AIR TRAFFIC ANALYSIS PROGRAM

Prepared by the MITRE Corporation, Bedford, Mass. for Electronic Systems Division, Air Force Systems Command, USAF, Hanscom Field, Bedford, Mass.; MITRE Technical Report MTR-2389, and also ESD-TR-328.

Describes a computer program to analyze air traffic in the North Atlantic ocean area. Three program options allow the user to obtain a bird's-eye view of the zone traffic at a specified instant of time, determine the flights which pass through a specified geographic box, and determine the time order and latitude of flights crossing a specified longitude. Typical results showing the instantaneous airborne count, amount of traffic passing through a geographic zone and number of flights per hour versus time are given for two days in 1972. Data was extracted from OAG (Official Airline Guide).

P. G. Reich (RAE) March 1961
PRELIMINARY STUDIES FOR MODELS OF FUTURE NORTH ATLANTIC AIR TRAFFIC CONTROL SYSTEMS

Royal Aircraft Establishment, Farnborough, England; RAE Technical Note, Math 77; also published in Proceedings of First Annual International Aviation Research and Development Symposium, Federal Aviation Agency.

An expanded title is also listed; Preliminary Studies for Models of Future North Atlantic Air Traffic Control Systems with Particular Reference to Supersonic Flight.

Two extreme forms of air traffic control are discussed. An attempt is made to characterize future supersonic traffic flow on North Atlantic routes. Separation standards which are appropriate to fixed-track systems are derived. Some simple models are discussed with reference to safety and economic factors.

P. G. Reich (RAE) March 1963
AN EXERCISE IN COSTING THE EFFECT OF AIR TRAFFIC CONTROL RESTRICTIONS ON NORTH ATLANTIC TRAFFIC

Royal Aircraft Establishment, Farnborough, England; RAE Technical Note, Math 90.

The costs borne by airline operators as a result of restrictions by Oceanic Traffic Control are estimated for the North Atlantic for 1961, 1964, and 1967. The 1964 and 1967 estimates are based upon fixed-track systems adjusted to the daily wind forecast. The analytical techniques used necessarily aim at an average interpretation of a wide variety of factors. As they may be controversial, they are described in detail. High, low, and intermediate estimates are presented to indicate the variability of this sort of exercise. Some methods for designing a route structure for least overall cost are described.

P. G. Reich and R. Towns April 1963
AN ANALYSIS OF JET TRAFFIC CROSSING THE NORTH ATLANTIC ON THE 7th and 8th OF SEPTEMBER, 1962.

Royal Aircraft Establishment, Farnborough, England; RAE Technical Note, Math 97.

P. G. Reich November 1964
A THEORY OF SAFE SEPARATION STANDARDS FOR AIR TRAFFIC CONTROL

Royal Aircraft Establishment, Farnborough, England; RAE Technical Report 64041, Departmental Reference: Math 124; also published separately as NASA N65-20667 (November 1964) by National Aeronautics and Space Administration (NASA, U.S.).

Expressions for collision risk are given in terms of elementary probabilities and of frequencies with which aircraft pass each other in the three dimensions of space. Techniques are proposed for setting confidence limits to estimates of the probabilities, including those that depend on the occurrence of large, rare, flying errors, so that similar confidence may be placed in estimates of collision risk. The large errors are represented by three alternative mathematical descriptions, so that the decision-maker, when considering proposals for separation standards, can compare the effect of alternative key assumptions on the estimated risk of collision.

P. G. Reich November 1964
AN ANALYSIS OF PLANNED AIRCRAFT PROXIMITY AND ITS RELATION TO COLLISION RISK, WITH SPECIAL REFERENCE TO THE NORTH ATLANTIC REGION, 1965-1971

Royal Aircraft Establishment, Farnborough, England; RAE Technical Report 64042; 2nd of 3 in numerical sequence.

Expressions are derived for the number of collisions to be expected within a traffic area in a period of time. These are given in terms of the frequency of large flying errors and the total time during which aircraft fly nominally at or near a statutory minimum of separation from each other (called "proximity"). Theoretical techniques are developed to study the variation of proximity, and hence of collision risk, with increases in the general level of traffic and with changes in the diurnal traffic pattern. Results of the theory are compared with observations of proximities in the North Atlantic region in the years 1965-71, based on traffic forecasts for this period.

P. G. Reich November 1964
SEPARATION STANDARDS IN THE NORTH ATLANTIC REGION, 1965-1971, IN THE LIGHT OF RECENT MEASUREMENTS OF FLYING ERRORS

Royal Aircraft Establishment, Farnborough, England; RAE Technical Report 64043, Math 126.

Interpretations are proposed for the sets of measurements which have been made of track-keeping and height-keeping errors. From these measurements, estimates are made of the elementary probabilities and frequencies which make up the expression for collision risk derived in earlier papers of this series. Assessments are then made of the levels of safety implied in various lateral and vertical separation standards, which might be considered for the North Atlantic region, for the forecast traffic in the period 1965-1971. There is also a brief discussion of longitudinal separation, for which there is not yet sufficient data to allow useful estimates of collision risk.

P. G. Reich (RAE) April 1965
THE RAE STUDIES OF SEPARATION STANDARDS AND COLLISION RISK: PART I, A THEORY OF SAFE SEPARATION STANDARDS FOR AIR TRAFFIC CONTROL: PART IV, THE EXTENT OF FLIGHT TRIALS NEEDED TO EVALUATE A NAVIGATION SYSTEM FOR CIVIL AIR TRANSPORT

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE, (Miami), working papers.

Presents a theory for relating air traffic control separation standards to collision risk. The theory (Part I) considers errors in aircraft track-keeping, and the influence of traffic density and route configuration. Presents for the consideration of "responsible authority" some alternative key assumptions. Application of the theory to the specification of navigation systems and their testing is discussed in Part IV.

See also Treweek, Reich, and Attwooll, "The Analytical Approach to Safety and Economic Factors...," April 1965.

P. G. Reich and R. Anderson (RAE) November 1965
SEPARATION STANDARDS IN THE LONG-RANGE AIR TRAFFIC CONTROL REGION - WITH SPECIAL REFERENCE TO VERTICAL SEPARATION

Royal Aircraft Establishment, Farnborough, England; Report RAE Technical Report RAE-TM-Math-68; 20 pages.

Discusses requirements for estimating safe separation standards, and for specifying the quality of navigation needed for given standards to be safe. The rare, large, flying errors are crucial to safe separation and their incidence cannot be deduced by theory. The report therefore stresses the importance of getting data in operational conditions and it emphasizes the part which aircrews can play in collecting observations. Given a reasonably large sample of true operational data (such as can be obtained with moderate effort and cooperation), the selection of safe separation standards is a task in which operational judgment must be combined with mathematical analysis. Standards must be put on a sound statistical basis, as well as being operationally and economically satisfactory.

P. G. Reich — January, April, and July 1966
ANALYSIS OF LONG-RANGE AIR TRAFFIC SYSTEMS

Journal of the Institute of Navigation (U.K.), London, England;
Vol. 19, Nos. 1, 2, and 3.

A four-part series of papers which describes the work of the Royal Aircraft Establishment on various aspects of air collision risk and traffic control; parts 1, 2, and 3 are by P. G. Reich, Part 4 is by V. W. Attwooll. All four parts relate to the size of separation standards.

In "Separation Standards, Part 1," P. G. Reich outlines the approach taken by the RAE to the problems of estimating collision risk and of specifying the navigational performance necessary to make separation standards safe. In "Separation Standards, Part 2," he discusses some of the theoretical techniques developed at the RAE. In "Separation Standards, Part 3," he gives some examples of applying the techniques to lateral and vertical separation standards.

In "Costing Air Traffic Control Deviations, Part 4," V. W. Attwooll discusses how air traffic control deviations relate to the size of separation standards, and he describes methods of costing the effects of air traffic deviations.

Reich's "Separation Standards, Parts 1 and 2" were also published by the U.S. National Aeronautics and Space Administration (Washington, D.C.) as technical documents NASA No. A66-20431 and NASA No. A66-29623, respectively.

P. G. Reich (RAE) — April 1966
ANALYSIS OF LONG-RANGE AIR TRAFFIC SYSTEMS: SEPARATION STANDARDS, II

Journal of the Institute of Navigation (U.K.), London, England;
Volume 19, No. 2.

In the first part of this series of papers, the approach of the Royal Aircraft Establishment to the problems of estimating collision risk, and of specifying the quality of navigation needed to make separation standards safe was outlined. A list was given of seven "requirements" for relating separation standards to collision risk. In this paper, some of the theoretical techniques developed at RAE to satisfy five of these requirements are discussed. Three Appendixes, not published in the Journal but available, deal with the frequency of losing separation in one dimension, the computation of P's from the assumed tail shapes, and the treatment of relative errors.

P. G. Reich and R. G. Anderson (RAE) — May 1966
SPECIFYING THE CALIBRATION OF STATIC PRESSURE SYSTEMS FOR THE SAFE USE OF 1000 FT. VERTICAL SEPARATION STANDARD IN NORTH ATLANTIC JET TRAFFIC

Royal Aircraft Establishment, Farnborough, England;
RAE Technical Report 66156.

R. G. Reich July 1966
ANALYSIS OF LONG-RANGE AIR TRAFFIC SYSTEMS: SEPARATION STANDARDS, PART 3

Journal of the Institute of Navigation (U.K.) London, England: Vol. 19, No. 3.

Of a four-part series of papers in the Journal entitled "Analysis of Long-Range Air Traffic Systems," P. G. Reich wrote three on "Separation Standards" (Parts 1, 2, and 3) and V. W. Attwooll wrote the fourth on "Costing Air Traffic Control Deviations."

In this, Part 3, P. G. Reich gives some examples of applying techniques developed at the Royal Aircraft Establishment (Farnborough) to satisfy five of seven requirements for relating separation standards to collision risk. The techniques themselves were discussed in Part 2, and the approach of the RAE to estimating collision risk and of specifying the navigational performance required to make separation standards safe was outlined in Part 1.

P.G. Reich Spring 1968
RAE STUDIES OF SEPARATION STANDARDS

The Journal of the Guild of Air Traffic Control Officers (U.K.); Vol. 4, No. 5.

The Reich papers previously published in the Journal of the Institute of Navigation (U.K.) have already described the principles and techniques developed at or used by the Royal Aircraft Establishment in the RAE approach to estimating collision risk and determining navigational performance requirements required to make separation standards safe. Observations of flying errors are emphasized throughout the RAE studies.

The main purpose of this paper is to give some examples of the application of RAE techniques to standards of lateral separation and vertical separation. The examples draw on results of the studies of jet traffic in the North Atlantic region, but the methods are shown to be applicable to other areas.

P.G. Reich (Ministry of Defense) July 1971
INFLUENCE OF LAND AND AIRSPACE DEMANDS ON CONTROL TECHNIQUES IN CURRENT USE

Journal of Navigation (U.K.), London, England; Vol. 24, No. 3.

J. J. Renes (NLR) October 11, 1974
PRELIMINARY REMARKS ON THE RESULTS OF THE STATISTICAL ANALYSIS OF THE EUROCONTROL MAIN SSR DATA COLLECTION OF 1972

Netherlands National Aerospace Laboratory (NLR), NLR Memo WM/VV/74-011; published as Working Paper 56 of Working Group "C" of the ICAO Review of the General Concept of Separation Panel by the International Civil Aviation Organization (ICAO/RGCSP-CWP-56).

his paper may or may not be identical with another listing (date and publishing source missing) by J. J. Renes of the NLR: "First Results of Collision Risk Calculations Using Data of About 4,000 Flights Processed by CIT."

Resalab, Inc. July 1972
LATERAL SEPARATION: VOL. I, STUDY RESULTS

Resalab, Incorporated, Dallas, Texas; Final Report No. FAA-RD-72-58, I.

In Volume I, a method is provided for determining minimum lateral spacings between runways and measuring the relative safety for a given runway.

The two-volume study is one of the most lively of the air traffic system separation studies performed in the current decade. The report arrives at its determinations of lateral spacing between runways and develops the essential equations by use of techniques which can be analogously translated from terminal area application to enroute system application by the researcher probing the literature.

Resalab, Incorporated July 1972
LATERAL SEPARATION: VOLUME II, STUDY APPROACH

Resalab, Incorporated, Dallas, Texas; for FAA SRDS, Washington D.C.; FAA-RD-72-58, II.

In this volume, Volume two of the report, data essential to the determination of minimum lateral spacings between runways are presented, including probability of collision data, "normal operating zone" data, and blunder recovery data. Includes development of techniques used to generate this data. Probability density functions for error of location of aircraft operating IFR, the Fokker-Planck equation, and a parametric variation on the pertinent system parameters were used respectively to generate probability of collision data, the lateral error probability density functions, and blunder recovery data.

The report arrives at determinations of lateral spacing between runways and develops the essential equations by use of techniques which can be analogously translated from terminal area application to enroute system application.

Louis W. Roberts, (DOT) TSC October 1972
FUTURE TRENDS IN AIR TRAFFIC CONTROL TECHNOLOGY

International Air Transport Association, Montreal, Canada;

Working paper presented at IATA 19th Technical Conference, Dublin, Ireland, October 23-28, 1972, by Louis W. Roberts, Transportation Systems Center (DOT-TSC), Cambridge, Mass.; IATA Conference 19/WP-18.

Assesses relevant technologies and possible future trends which would have potential for application to advanced air traffic management systems (AATMS).

R. T. Robinson January 1965
ASSESSMENT OF CHANGES IN COLLISION RISK OF NORTH ATLANTIC AIR TRAFFIC FROM CHANGES IN THE REPORTED SIGHTING RATE

Royal Aircraft Establishment, Farnborough, England; RAE Technical Report 65002.

W. P. Robinson (BOAC) July 1971
AREA NAVIGATION

Journal of Navigation (U.K.), London, England; Vol. 24, No. 3.

In this paper, W. P. Robinson of the British Overseas Airways Corporation, London Airport, discusses the expected benefits to the present ATC system to be derived by use of area navigation. He cites as typical benefits of area navigation, bypass tracks, multitracks for segregation of air traffic by speed or flight configuration, multitracks for omnidirectional traffic flow, improved alignment of routes resulting in cost benefit, enhancement of holding pattern sizing and siting, enhancement of STOL and helicopter operational procedures.

E. Roessger and G. Raenike (Technical University of Berlin) April 1965
THE CALCULATION OF MINIMUM-TIME TRACKS BY DIGITAL COMPUTER

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE (Miami) April 22-30, 1965.

Minimum-time tracks for civil aircraft are usually constructed by graphical methods. To improve on the limited accuracy and slowness of graphical methods, the authors suggest that a method depending on an analogy with Huygens' laws of refraction can be adapted to a digital computer. With a relatively small computer, the calculation of the track from London to New York can be completed in 90 seconds.

E. Roessger and G. Raenike (Tech. Univ. of Berlin) April 1965
A DEVICE FOR DEMONSTRATING FLIGHT LEVELS, ALTIMETER READINGS, TRANSITION ALTITUDE, ETCETRA

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE, (Miami); working paper WP-19.

This paper may or may not be identical with another listing (date and publishing source missing) by J. J. Renes of the NLR: "First Results of Collision Risk Calculations Using Data of About 4,000 Flights Processed by CIT."

Resalab, Inc. July 1972
LATERAL SEPARATION: VOL. I, STUDY RESULTS

Resalab, Incorporated, Dallas, Texas; Final Report No. FAA-RD-72-58, I.

In Volume I, a method is provided for determining minimum lateral spacings between runways and measuring the relative safety for a given runway.

The two-volume study is one of the most lively of the air traffic system separation studies performed in the current decade. The report arrives at its determinations of lateral spacing between runways and develops the essential equations by use of techniques which can be analogously translated from terminal area application to enroute system application by the researcher probing the literature.

Resalab, Incorporated July 1972
LATERAL SEPARATION: VOLUME II, STUDY APPROACH

Resalab, Incorporated, Dallas, Texas; for FAA SRDS, Washington D.C.; FAA-RD-72-58, II.

In this volume, Volume two of the report, data essential to the determination of minimum lateral spacings between runways are presented, including probability of collision data, "normal operating zone" data, and blunder recovery data. Includes development of techniques used to generate this data. Probability density functions for error of location of aircraft operating IFR, the Fokker-Planck equation, and a parametric variation on the pertinent system parameters were used respectively to generate probability of collision data, the lateral error probability density functions, and blunder recovery data.

The report arrives at determinations of lateral spacing between runways and develops the essential equations by use of techniques which can be analogously translated from terminal area application to enroute system application.

Louis W. Roberts, (DOT) TSC October 1972
FUTURE TRENDS IN AIR TRAFFIC CONTROL TECHNOLOGY

International Air Transport Association, Montreal, Canada;

Working paper presented at IATA 19th Technical Conference, Dublin, Ireland, October 23-28, 1972, by Louis W. Roberts, Transportation Systems Center (DOT-TSC), Cambridge, Mass.; IATA Conference 19/WP-18.

The original title of the IATA 16th Technical Conference working paper was longer: "Model and Slide Rule to Demonstrate the Relative Vertical Position of the Flight Levels, the QNH Altitudes, the QFE Heights, the Transition Altitude, the Transition Level, and the Transition Layer." The "Q Signals" decoded in ICAO Doc. 8400/3:QNH-Altimeter subscale setting to obtain elevation when on the ground; QFE - Atmospheric pressure at aerodrome elevation (or at the runway threshold).

This paper describes a device, which may take the form of a slide rule or a pictorial presentation, that demonstrates the algebraic sum of the factors involved in the relation between "flight level," QNH altitude, QFE height, transition altitude, transition level, and transition layer. It may serve to facilitate vertical control on entering the terminal area.

The relationship of the "ambiguities" in vertical position reporting to separation and safety are found in the FAA statement in Airman's Information Manual,"...a high percentage of near mid-air collisions occur below 8000 feet AGL and within approximately 30 miles of an airport with a control tower."

The authors are associated with the Institute for Air Navigation and Air Transportation, Technical University of Berlin.

E. Roessger and G. Raenike (Tech. Univ. of Berlin) April 1965
A SIMPLE QFE AND QNH INDICATOR AND A SLIDE RULE FOR THE DETERMINATION OF THE QNH FROM THE QFE

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE (Miami); working paper WP-22.

The authors are associated with the Institute for Air Navigation and Air Transportation, Technical University of Berlin. In Working Paper 20 of IATA Conference 16, they describe instruments which show the algebraic sum of the quantities QFE (atmospheric pressure at aerodrome elevation), QNH (altimeter subscale setting to obtain elevation when on the ground), and the altitude of the airport. The authors postulate that these instruments may facilitate vertical control on entering terminal areas.

Obviously the procedural mathematics put forth in the several papers by Roessger and Raenike are directed primarily to the interests of the operational flight crew. However, they comprise categories of observations which may become input data for separation study analyses. It is suggested that some attention to these efficient reports may reward the researcher with awareness of "real-world" considerations.

Russel Rollin, Hodge Doss, Elmer Smith, and Randall Cline April 1964
(Univ. of Mich.)
INVESTIGATION OF PRECISION POSITION DETERMINATION BY DISTANCE-MEASURING TECHNIQUES

University of Michigan, Ann Arbor, Michigan; under Contract DA-36-039-SC-78801 for Dept. of the Army.

Project MICHIGAN (a long-range program for advancing Army's combat-surveillance and target-acquisition capabilities) focusses on MTI radar, imaging radar, radio location, and infrared and other special investigations. Discusses such techniques as HIRAN, LORAN, SHORAN, the geodimeter, and the tellurometer.

Stanley N. Roscoe and E. F. Kraus Fall 1973
(Univ. of Ill. and McDonnell-Douglas)
PILOTAGE ERROR AND RESIDUAL ATTENTION: THE EVALUATION OF A PERFORMANCE CONTROL SYSTEM IN AIRBORNE AREA NAVIGATION

Journal of the Institute of Navigation (U.S.) Washington, D.C.; NAVIGATION: Vol 20, No. 3. Paper presented at the International Navigation Congress, Hanover, Germany, October 4, 1973, by Dr. C. O. Hopkins of the University of Illinois, on behalf of the authors.

As recapitulated in introductory paragraphs, pilotage error is an essential component of navigational course deviation, or "flight technical error." The latter, in turn, is one of the critical considerations in specifying defined airway widths. At that ultimate point in a rationale, airspace regulation is the issue. This paper discusses "error budget" and the contribution made to it by pilotage error. See slso similar material in "Assessment of Pilotage Error.." by Roscoe, published in Human Factors, 16, 3, June 1974 (Johns Hopkins University Press).

Stanley N. Roscoe (Univ. of Ill.) June 1974
ASSESSMENT OF PILOTAGE ERROR IN AIRBORNE AREA NAVIGATION PROCEDURES

Johns Hopkins University Press, Baltimore, Maryland; in Human Factors: Journal of the Human Factors Society, Vol 16, No. 3, pp. 223-228.

The publication of Advisory Circular AC-90-45, titled, "Approval of Area Navigation Systems for Use in the U.S. National Airspace System," (FAA 1969) "implemented an empirically quantitative basis for determining airways route widths in this country." Thus the FAA "legally attached economic premiums and penalties to human performance, as well as equipment performance, in man-machine system design." Flight experimentation and simulation are both required to establish the accuracy of use and freedom from blunders associated with systems involving displays and controls. This paper describes an automatically adaptive side task which provides a saturating level of pilot

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AIR TRAFFIC SEPARATION STUDIES: AN ANNOTATED LISTING OF READING--ETC(U)
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workload and allows the statistically reliable measurement of a pilot's residual attention in a sensitive and orderly manner. This is proposed as a common metric for area navigation system assessment.

Closely related to paper in NAVIGATION-Fall 1973, by Roscoe and Kraus of the University of Illinois, "Pilotage Error and Residual Attention" (q.v.).

R. Rose and F. Dee (RAE) 1963
AIRCRAFT VORTEX WAKES AND THEIR EFFECTS ON AIRCRAFT

Royal Aircraft Establishment, Farnborough, England;
RAE Technical Note Aero 2934.

D. A. Rossman and R. J. Kirchoff (Date missing)
GROUND-BASED COLLISION AVOIDANCE FUNCTION FOR THE 1980 AIR TRAFFIC CONTROL SYSTEM

IBM Corporation, Gaithersburg, Maryland.

RTCA May 3, 1955
REEVALUATION OF VOR-AIRWAY LATERAL SEPARATION CRITERIA

Radio Technical Commission for Aeronautics, Washington, D.C.;
Special Committee 62 paper SC-62/86-55 DO-63, 98 pages.

RTCA November 1968
ALTIMETRY

Radio Technical Commission for Aeronatuics, Washington, D.C.;
RTCA Paper 215-58/0088.

R. A. Rucker (MITRE) September 1975
AVIATION COLLISION RISK IN U.S. VS. AIRWAY LATERAL SEPARATION STANDARDS--A HISTORICAL PERSPECTIVE

The MITRE Corporation, McLean, Virginia; MITRE Technical Report MRT-7030.

Promotes the thesis that there is "virtually no evidence to suggest" that the present United States lateral separation standard for airways has been a contributing factor in any collision involving at least one IFR aircraft. This paper was provided at the ICAO RGCSP 3rd Meeting (Montreal, August-September 1975) as "U.S. Background Information Paper No. 4."

R. A. Rucker (MITRE) November 1975
AUTOMATED IFR TRAFFIC CONTROL: PROJECT OVERVIEW & OBJECTIVES

The MITRE Corporation, McLean, Virginia; MITRE Technical Report MTR-7073 for DOT-FAA/OSEM. Also published as FAA-EM-75-10.

Summary remarks on increased automation in future ATC are very worthwhile. Self-described as a digital computer simulation of automated control of IFR air traffic through an enroute arrival sector. Discusses current plans for improvement of that model with applications touching on data link, conflict prediction and resolution, controller productivity, and the Upgraded 3rd Generation ATC system (UG3rd).

Real-world events expedited implementation of separation procedures based on the marriage of Digital Processed Radar and Conflict Prediction.

James F. Rudolph (FAA, Flight Standards Service) 1973
AIRCRAFT WAKE TURBULANCE

Flight Safety Foundation, Inc., Arlington, Virginia; in "Economics of Air Safety and Long-Range Safety Research and Development," Proceedings of the Twenty-Sixth Annual International Air Safety Seminar, Lisbon, Portugal, November 4-7, 1973.

Discussion of an FAA R&D program aimed at coping with current wake vortices problems which are significant in large transport aircraft. The program is planned to increase aircraft safety in terms of vortex hazard and allow a large increase in airport capacities by reducing the takeoff and landing spacing. The major points of the program include aircraft design modifications for wake vortex elimination, vortex dissipation methods, and automatic wake vortex avoidance systems.

R. H. Sawyer, M. D. McLaughlin, and N. S. Silsby July 1968
SIMULATION STUDIES OF THE SUPERSONIC TRANSPORT IN THE PRESENT-DAY AIR TRAFFIC CONTROL SYSTEM

National Aeronautics and Space Administration, Washington, D.C.; NASA Technical Note D-4638.

M. E. Schucart and J. B. Arnett (North American Aviation, Inc.) April 1965
A PRELIMINARY ANALYSIS OF THE NORTH ATLANTIC ROUTE STRUCTURE AND NAVIGATIONAL SYSTEM ERROR

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: PROCEEDINGS OF THE 16th IATA TECHNICAL CONFERENCE, (Miami) working paper WP-41, possibly published in J.I.N., 1965 or later.

Because cruise-climb operations for the SST are desirable from an economic point of view, a single layer flight structure should be maintained. This will be made easier by more accurate navigation systems to reduce the lateral separation of air-lanes. Position errors within the lane also add to operational costs, since more fuel must be used, or carried, to correct them.

L. Schuchman (MITRE) October 1975
AN ACTIVE BEACON-BASED COLLISION AVOIDANCE SYSTEM CONCEPT (BCAS)

The MITRE Corporation, McLean, Virginia; MITRE Technical Report MTR-7036, for DOT-FAA/OSEM. Also published as FAA-EM-75-7.

Describes the concept of an active Beacon Collision Avoidance System (BCAS). Defines the system design which enables BCAS to minimize the critical problem of garble, and the design constraints of this air-to-air collision avoidance system. Presents results of dynamic simulation studies of air traffic system models based on Los Angeles Basin and the Washington National Airport.

This paper deals only with an all-active BCAS concept. In contrast, for example, there is a BCAS wiich has a passive mode which is being developed by Mr. George Litchford. In the Litchford system, the equipment user listens to ATCRBS ground interrogators and airborne replies to determine the range, altitude, and bearing of target aircraft.

The report does comment superficially concerning the impact of this ATCRBS/CAS concept on the air traffic control radar beacon system in controlled and uncontrolled airspace, and on its complementary interface with the DABS/IPC environment, in the opinions of its author.

G. A. Scott (FAA) April 1975
NEW HORIZONS IN AIR TRAFFIC CONTROL

American Institute of Aeronautics and Astronautics, Digital Avionics System Conference, Boston, Mass.; paper 75-569, 7 p.

According to the FAA's air traffic forecasts, aviation in the United States will continue to grow into the indefinite future. To meet the demands of this continuing growth, the existing air traffic control (ATC) system must be improved. The goals of the future upgraded ATC system are to maintain or improve safety, constrain or reduce costs, and increase and improve performance. These goals will be met in part by the following new ATC features: Airport Surface Traffic System (ASTC), Discrete Address Beacon System (DABS), Air Traffic Control Automation, Intermittent Positive Control (IPC), Area Navigation (RNAV), Microwave Landing System (MLS), and Wake Vortex Avoidance System (WVAS).

P. P. Scott April 1968
STUDIES OF TRAFFIC PACKING FOR ESTIMATING MID-AIR COLLISION RISKS OVER THE NORTH ATLANTIC

Royal Aircraft Establishment, Farnborough, England; RAE Technical Report 68097.

Describes studies of traffic patterns for the North Atlantic, and relationships between daily operations counts, route utilization and traffic density, adjacent traffic occupying nearby routes or flight levels, and other measures of "close-packing." From traffic forecasts, estimates are then made of route occupancies during the period 1969-1974. These estimates are presented in the form of distributed variables which can be fed into a Monte Carlo process for solving collision-risk equations. The Monte Carlo process has been selected by international agreement.

P. P. Scott February 1974
A SIMULATION MODEL OF AIR TRAFFIC ALLOCATION TO THE NORTH ATLANTIC TRACK SYSTEM

Royal Aircraft Establishment, Farnborough, England; RAE Technical Report 73180, Departmental Reference: Math 217.

A study aimed at forecasting the density which will affect the risk of mid-air collision, and which, therefore, will influence the sizes of separations between flight paths.

Robert E. Scott (University of Michigan) August 1969
STUDY AND EVALUATION OF THE OMEGA NAVIGATION SYSTEM FOR TRANSOCEANIC NAVIGATION BY CIVIL AIRCRAFT

Federal Aviation Administration, Washington, D.C.; Technical Report No. FAA-RD-69-39.

S. M. Serebreny April 1965
THE INTERRELATION OF CRUISE FUEL CONSUMPTION, TEMPERATURE, AND TRACK SELECTION IN SUPERSONIC TRANSPORT OPERATIONS

Journal of the Institute of Navigation (U.K.), London, England; Vol. 18, No. 2.

Mr. Serebreny is associated with the Aerophysics Laboratory of Menlo Park, California.

R. R. Shaw (IATA) April 1966
TEXT ON REMARKS BY THE TECHNICAL DIRECTOR DESIGNATE, INTERNATIONAL AIR TRANSPORT ASSOCIATION, TO FAA

Federal Aviation Administration, Washington, D.C.; U.S. Government Printing Office, Washington, D.C.

Public Hearing on Lateral Separation over North Atlantic, Washington, D.C.

David J. Sheftel (FAA) April 1965
SUMMARY OF PROJECT ACCORDION DATA

International Air Transport Association, Montreal, Canada; AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE, (Miami) working paper WP-103.

Summarizes and discusses the data collected during "Project Accordion" in 1962 and 1963. "Operation Accordion" proposed to measure the operational accuracy of doppler and other navigational systems in civil air transport over the North Atlantic. The measurement of accuracy was made by comparison of the subject data with aircraft positions reported by ground-based radar.

D. J. Sheftel and S. Hirshon (FAA) April 1965
FLIGHT EVALUATION OF INERTIAL NAVIGATION AND GUIDANCE FOR CIVIL AIR TRANSPORT

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE, working paper WP-104.

W. Siddiquee (Stanford) Winter 1973-1974
AIR ROUTE CAPACITY MODELS

Journal of the Institute of Navigation (U.S.), Washington, D.C.; NAVIGATION: Vol. 20, No. 4.

Dr. Waheed Siddiquee of Stanford Research Institute, Menlo Park, California, submitted this paper for publication, December 1, 1972, one year before its publication in this issue of NAVIGATION. Three simple air route capacity models are developed. These models were derived by Stanford Research Institute after in-depth study of air route capacity. They are intended as preliminary design aids for planners and designers of air route networks. And they were thus applied in the Stanford effort reported by R. S. Ratner, et al., in "The Air Traffic Controllers' Contribution to ATC System Capacity" (vols. I and II), published by Stanford Research Institute.

Colin G. Simpson (FAA) November 1973
RECENT DEVELOPMENT IN AIRCRAFT SAFETY, AIR TRAFFIC CONTROL, AND NAVIGATION

Flight Safety Foundation, Inc., Arlington, Virginia; in "Economics of Air Safety and Long-Range Safety Research and Development," proceedings of the 26th International Air Safety Seminar, Lisbon, Portugal, November 4-7, 1973.

Reviews recent developments in aircraft safety and air traffic control from the work of FAA Engineering and Development. In a program for upgrading the U.S. air traffic control and navigation system to serve requirements forecasted for the next thirty years, the important elements are a discrete address beacon system, a collision avoidance system, and a proximity warning indicator. The report also discusses airworthiness, crashworthiness, and development of the MLS (microwave landing system).

William E. Simpson, OSEM/DOT October 1972
FUTURE SYSTEM CONCEPTS FOR AIR TRAFFIC MANAGEMENT

International Air Transport Association, Montreal, Canada; presented at the 19th IATA TECHNICAL CONFERENCE (Dublin, Ireland); working paper WP-17.

Discusses briefly the impact of predicted demands in the 1995 period, and describes two alternative system mechanization concepts.

Lakshman P. Sinha October 1973
BOUNDS ON ATTAINABLE ACCURACIES IN TRACKING AIRCRAFT WITH TELEMETERED TURN INFORMATION

The MITRE Corporation, McLean, Virginia; MITRE Technical Report MTR-4465 (Series 5).

Lakshman P. Sinha (MITRE) August 1974
STEADY STATE BIAS CHARACTERISTICS OF ALPHA-BETA TRACKERS

The MITRE Corporation, McLean, Virginia; MITRE Technical Report MTR-WP-7711 (Series 13); working paper (MITRE) reference number TOS 122-47.

Discusses steady state bias characteristics of (a-b) alpha-beta trackers. Necessary mathematical expressions for bias in position, speed and heading are derived; computational results are presented as a function of angular heading change in one scan for various combinations of the position and velocity estimating coefficients, alpha and beta, respectively. Also includes analysis of bias in position and heading when prediction is made for an extended period of time.

Dr. Lakshman P. Sinha (MITRE) April 1975
ANALYSIS OF NAS-ARTS REGISTRATION AND ADAPTATION ERRORS

The MITRE Corporation, Atlantic City, N.J.; MITRE Technical Report MTR-4251

Deals with the estimation of errors in the adapted coordinates of ARTS in the en route program. Also presents a simple, and computationally efficient technique of registering ARTS sensor under certain assumptions. Appendixes describe mathematical formulation of the estimation problem in detailed logical processes expressed algebraically, and also describe the estimation program itself (FORTRAN) together with extensive flow charts.

A. P. Smith (MITRE) February 1975
AN ASSESSMENT OF SEPARATION STANDARDS METHODOLOGIES APPLICABLE TO FUTURE OCEANIC ATC SYSTEMS

The MITRE Corporation, McLean, Virginia; MITRE Technical Report MTR-6767.

Seeks to identify parameters, concepts, and considerations affecting development of an adequate methodology to evaluate separation standards for an anticipated oceanic ATC system served by AEROSAT. Also seeks to evaluate the standpoint of their adequacies and deficiencies in terms of evaluating candidate oceanic ATC systems. An orderly recapitulation of past work and review of present program status.

Arthur P. Smith III (MITRE) January 1976
PARAMETRIC ANALYSIS OF ROUTE SPACINGS IN AN INDEPENDENT SURVEILLANCE-BASED OCEANIC ATC SYSTEM

The MITRE Corporation, McLean, Virginia; MITRE Technical Report MTR-7116, for FAA-OSEM.

Presents a parametric study of the oceanic lateral (route) separation which would be acceptable between aircraft flying at the same altitude and in the same direction under independent satellite surveillance. Investigates the system performance necessary to resolve aircraft blunders.

"Independent surveillance uses the range of the aircraft from each of two satellites whose positions are known, and the aircraft's reported altitude. Dependent surveillance uses the position, altitude, and time which are determined aboard the aircraft and relayed to the ground via one of the satellites," (Smith, MITRE 6767).

J. A. Sorensen, A. W. Merz, T. B. Cline, J. S. Karmarker, December 1973
W. Heine, and M. D. Ciletti (SCI)
HORIZONTAL COLLISION AVOIDANCE SYSTEMS STUDY

Systems Control, Inc., Palo Alto, California; Technical Report FAA-RD-73-203 for FAA SRDS, Washington, D.C.; also issued as DOT-TSC-73-36, by the Department of Transportation, Transportation Systems Center, Cambridge, Mass.

An analytical study of the merits and mechanization requirements of horizontal-collision avoidance systems (CAS). The maneuvers (both horizontal and horizontal/vertical) are found which provide minimum off-track deviation and acceptable turn rates, together with adequate miss-distance with minimum initial range. An algorithm is developed for computing appropriate collision-avoidance maneuvers. System measurement statistics are computed, such as false alarm rates, missed alarm rates, near-miss probability, and collision rate. Extensive bibliography.

J. A. Sorensen, A. W. Merz, T. B. Cline, and J. S. Karmarker August 1974
AIRCRAFT GUIDANCE FOR AUTOMATIC COLLISION AVOIDANCE

Transportation Systems Center, U.S. Department of Transportation, Cambridge, Mass.; Contract No. TSC-535, paper presented at the Sixth Symposium on Automatic Control in Space (IFAC, International Federation of Automatic Control), August 1974 at Tsakhkadzor, Armenian SSR.

Discusses the development of guidance system requirements for automatic prevention of aircraft collisions. The guidance commands can be computed as part of the air traffic control function, or by means of an independent

airborne collision avoidance system. The general problem is divided into three parts: determination of the most effective maneuvers, development of computer algorithms to estimate threats and generate evasive maneuvers accordingly, and determine the effects of dynamic errors and measurement errors on system performance.

H. R. Spahr and H. A. Sumlin September 1975
INTERACTIVE COMPUTER GRAPHICS APPLIED TO THE THEORETICAL AIRCRAFT/STORE SEPARATION PROBLEM

Computers and Graphics, Vol. 1.

Paper presented by Sandia Laboratories (Albuquerque) at Conference on Computer Graphics, Boulder, Colorado, July 1974, sponsored by University of Colorado. Research supported by AEC (Atomic Energy Commission).

A computer program was developed which computes the theoretical trajectory of a store in the complex flow field after release from an aircraft flying at subsonic speeds. Construction of the source and sink models, which are part of the computer input, presented a problem. An interactive graphics computer program ("SOURCE") is used to prepare source and sink theoretical aerodynamic models for the aircraft fuselage, nacelles, fuel tanks, and store bodies. Use of this interactive graphics computer program reduces the calendar time required to develop the source and sink model from about two weeks to one hour. This economy is of interest when the store shape is frequently being changed in a development program.

R. Dixon Speas Associates October 1972
AIR TRAFFIC DEMAND DISTRIBUTION MODELS FOR EVALUATION OF FUTURE AIR TRAFFIC CONTROL CONCEPTS

International Air Transport Association, Montreal, Canada; paper presented at 19th IATA TECHNICAL CONFERENCE (Dublin, Ireland), by R. Dixon Speas Associates, Manhasset (Long Island), New York; working paper WP-19.

Discusses the design of an ATC demand distribution model and its use for ATC system evaluation.

L. Stachtchenko July 1965
AN INVESTIGATION OF AIRCRAFT COLLISION RISKS OVER THE NORTH ATLANTIC

Journal of the Canadian Operational Research Society, Vol. 3.

The aircraft collision risk over the North Atlantic is investigated by measuring navigation errors via radar. The error distribution was found to be non-Gaussian.

H. Staras and R. W. Klopfenstein 1960
A STATISTICAL ANALYSIS OF CROSS-TRACK ERRORS IN NAVIGATION SYSTEMS UTILIZING INTERMITTENT FIXES

IRE Transaction on Aeronautical and Navigational Electronics, Vol. ANE-7, No. 1; Institute of Radio Engineers. The IRE was subsequently reorganized as Institute of Electrical and Electronics Engineers (IEEE), New York, New York.

Stuart H. Starr and Dr. Barry Horowitz (MITRE) Winter 1970-71
APPLICATION OF OPTIMAL CONTROL THEORY TO SATELLITE-BASED OCEANIC AIR TRAFFIC CONTROL

NAVIGATION: Journal of the Institute of Navigation (U.S.), Washington, D.C.; Volume 17, No. 4, pages 337-348.

Describes the application of stochastic optimal control theory to the design and analysis of a satellite-based ATC system for the North Atlantic. The simulated environment includes errors arising from navigation, wind, and surveillance. The control algorithm includes a Kalman filter in tandem with an optimal regulator, with adjustable update and command rates, and command thresholds. The analytical tool that is developed herein, can be used as a basis for deriving the expected separation standards to be used with a future satellite-based system. In addition, it can be used to determine the impact of design trade-offs on system performance.

H. A. Steinberg July 1969
A SAFETY MODEL FOR EVALUATING RISK INVOLVED IN AIRPORT LANDING OPERATIONS

Mathematical Applications Group, Inc., Document MR-6901, Report of U.S. Department of Transportation Air Traffic Control Advisory Committee, Vol. 2, Appendix B-2, December 1969.

Gives a general description of a safety model for aircraft landing on a single or close parallel runways. Calculations are performed which compare risk to runway separation of parallel runways with and without longitudinal control.

H. A. Steinberg March 1970
COLLISION AND MISSED APPROACH RISKS IN HIGH-CAPACITY AIRPORT OPERATIONS

Institute of Electrical and Electronics Engineers, Incorporated, New York, New York; Proceedings of the IEEE, Vol. 58, No. 3, p. 314.

A study is made to develop a risk model for airport landing operations. Particular emphasis is placed on simultaneous use of closely spaced parallel runways and on reduction of longitudinal separation on final approach. Based upon certain simplifying assumptions, the missed approach and collision rates

are evaluated. For the parameters considered it is found that a safe separation distance for parallel runways is approximately 2500 ft. Further, an acceptable missed approach rate can be maintained if the average spacing at the runway threshold is 62 seconds without speed adjustments on final approach; with some speed adjustments, 55 seconds is sufficient, assuming a runway occupancy time of 40 seconds.

D. E. Stepner and J. S. Tyler, Jr. (SCI) August 1971
THE COMPUTATION OF POSITION ERRORS FOR AIR TRAFFIC CONTROL SURVEILLANCE MODELS

Systems Control, Inc., Palo Alto, California; AIAA Paper No. 71-927; AIAA Guidance, Control, and Flight Mechanics Conference (Hempstead, N.Y., Hofstra University), August 16-18, 1971. American Institute of Astronautics and Aeronautics, Philadelphia, Pa. (Editorial Offices, New York, N.Y.).

Considers the development of a mathematical model for specifying parameters of a surveillance system in accordance with accepted standards of collision risks. A key parameter for specifying collision risk is the probability of overlap. This study relates probability of overlap to the surveillance system parameters by modelling the time-dependent behavior of an aircraft under the influence of a surveillance system. Appendix A treats "Assumptions and Development of Reich Model."

D. E. Stepner, W. Heine, and J. A. Sorensen (SCI) February 1973
OCEANIC AIR TRAFFIC CONTROL SURVEILLANCE SYSTEMS STUDY

Systems Control, Inc., Palo Alto, California; FAA-RD-73-8 for Federal Aviation Administration.

A general approach for modeling the interaction of the major elements of the Oceanic ATC system, which are the ATC procedures and the airborne navigation system. It is shown that the lateral separation standard can be reduced from 120 nautical miles to 45 nautical miles, and the longitudinal standard from 15 minutes to 10 minutes, provided all aircraft are equipped with INS (Inertial Navigation System). Further, the lateral separation can be further reduced to 30 nautical miles if an independent surveillance system is included. Extensive trade-off studies are made to determine the most sensitive parameters of the Oceanic ATC system.

D. E. Stepner September 1973
MODELLING OF AIRCRAFT POSITION ERRORS WITH INDEPENDENT SURVEILLANCE

AIAA Journal, Vol. 11, No. 9; American Institute of Aeronautics and Astronautics, Philadelphia, Pa.;

In oeder to reduce present air traffic separation standards, a means must be established of quantitatively measuring the safety level of a particular route structure. The distribution of aircraft position errors about their intended tracks is the most important factor in determining route safety. This paper, presented at the AIAA Eleventh Aerospace Sciences Meeting, Washington, D.C., January 10-12, 1973, offers a modelling technique which can compute the probability density function of position errors as the aircraft proceeds along the route. The technique takes into account not only the time dependence, but also all the factors influencing the aircraft's position errors, such as surveillance fix rate, and air traffic control procedures.

B. Stockwell February 1970
THE SPOT III SYSTEM

British Interplanetary Society Journal, Vol. 23, pp. 105-124.

Describes ATC needs for oceanic routes; demonstrates requirements for accurate position determination and improved air-ground communications; examines various techniques for position determination, and selects for implementation a ranging concept. The latter employs two satellites to provide two measurements of aircraft range which are used with the known altitude of the aircraft to determine precise position of the aircraft. Describes the total system and details of the functions of air traffic control, data transfer, and voice transfer. Also describes the various spacecraft supporting subsystems.

F. S. Stringer (RAE) April 1965
RESEARCH AND DEVELOPMENT RELATED TO NAVIGATION ON LONG-DISTANCE ROUTES

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE (Miami).

As presented to the Miami conference, the title was longer. The shorter title suggests that it was later published in Journal of the Institute of Navigation (U.K.). The paper establishes a familiar departure point, that a reduction in separation standards demanded by expected increasing traffic density will require more stringent navigational performance. Navigational sub-systems are then reviewed, both external-reference and self-contained. It is concluded that the future airborne navigation system must include both, and combine them by means of a digital computer. Communications requirements are also discussed.

J. T. Stultz (Sikorsky) February 1969
A NEW CONCEPT FOR AIRCRAFT SEPARATION STANDARDS

American Institute of Aeronautics and Astronautics, Philadelphia, Pa.; paper numbered AIAA 69-211, presented at the AIAA/AHS VTOL Research, Design, and Operations Meeting, Georgia Institute of Technology, Atlanta, Georgia (joint meeting with American Helicopter Society).

Describes some results of an Instrument Operations Study conducted by Sikorsky Aircraft (Stratford, Conn.) to consider high density air traffic operations, with special interest in enhancing VTOL or joint CTOL/VTOL terminal area movement. Determined that holding of air traffic is a control device which must be abandoned, the author proposes use of an ATC computer and state-of-the-art electronics technology to "modernize" reduced separation standards, and "continuous monitoring" of aircraft progress within reduced tolerances of track-keeping.

J T. Stultz and R. W. Dorozentski October 1969
V/STOL CONSIDERATIONS IN AIR TRAFFIC CONTROL

American Institute of Aeronautics and Astronautics, Philadelphia, Pa.; paper numbered AIAA 69-1055, presented at the AIAA Anual Meeting, ANaheim, California.

Discussion of V/STOL air traffic control and equipment considerations, with indication of a system to fulfill the needs as demand increases. In lieu of the distance separation technique which has been used to date, it is recommended that a time-velocity separation system be employed. Such a system can provide an efficient operation by using direct routing, positive control at all times, and automation in control at a high rate of system utilization.

Systems Research, Inc. 1973
ECONOMIC PENALTY TO NORTH ATLANTIC AIRLINE OPERATORS DUE TO ADHERENCE TO PRESENT-DAY SEPARATION STANDARDS

J. S. Szymkowicz (FAA) February 1967
ALTIMETRY

The Institute of Navigation (U.S.), Washington, D.C.; Proceedings of the ION National Air Meeting on Collision Avoidance, Dayton, Ohio, paper presented by the Federal Aviation Administration. Possibly also published by FAA in 1968.

Warren Taylor May 1959
A METHOD FOR ESTABLISHING SUITABLE VERTICAL SEPARATION BETWEEN AIRCRAFT FLYING ON THE AIRWAYS

Paper presented at the 15th National Meeting of the Operations Research Society of America.

Produced in 1959 and apparently unpublished (available as 12 pages of multi-printed typescript), Lt. Commander Warren Taylor (USN, Operations Analysis Directorate) was assigned to the Atlantic City experimental center (NAFEC) when this paper was presented at the 15th National Meeting of the Operations Research Society of America. It was possibly published in the appropriate "Proceedings." Applies the overlap of the tails of two distributions to collision risk in the vertical dimension.

Warren Taylor April 1960
A PROBABILITY MODEL OF THE AIRCRAFT SEPARATION PROBLEM

FAA Bureau of Research and Development, Atlantic City, New Jersey (later NAFEC).

The paper presents a mathematical model of the relationship between aircraft separation and flight variability for aircraft on airway routes in terms of collision probability. The development yields a closed form of this relationship which shows the effects of the three space dimensions and time itself on this problem. A discussion of the assumptions and approximations of the formulation are set forth in an appendix to the paper. A second appendix offers a manner for determining a point of diminishing return which provides a low collision hazard and at the same time trades off a small amount of separation to be provided for the aircraft.

See also "Author's Explanatory Comments on 'A Probability Model of the Aircraft Separation Problem'" (April 1960), published by FAA, Research Division, Atlantic City, N.J. (NAFEC).

Warren Taylor April 1960
AUTHOR's EXPLANATORY COMMENTS ON "A PROBABILITY MODEL OF THE AIRCRAFT SEPARATION PROBLEM"

Federal Aviation Administration (FAA) Research Division, Atlantic City, New Jersey (later NAFEC).

See also the reference paper, "A Probability Model of the Aircraft Separation Problem" (April 1960), FAA, Bureau of Research and Development, Atlantic City, N.J. (NAFEC).

Warren Taylor, F. K. Yost, and P. S. Ball, Jr. May 1960
MINIMUM SEPARATION OF DUAL PARALLEL RUNWAYS

Federal Aviation Administration (FAA) Research Division, Atlantic City, New Jersey (later NAFEC).

Or "Theoretical Minimum Separation of Parallel Runways."

F. W. Thesen March 1971
THE SEPARATION DILEMMA--ICAO EFFORTS TO OVERCOME IT

ICAO Bulletin, Vol. 26, No. 3.

An ICAO Panel, Review of the General Concept of Separation (RGCS), was formed in 1970 and held its first meeting in January 1971. The Panel will explore the possibility of developing an advanced theory of separation of aircraft, leading to a scientific method for establishing all forms of separation and methods for their application and, in so doing, will not close its eyes to possible future separation techniques not requiring the application of specific separation minima.

T. G. Thorne (RRE) and J. D. Ackerman (AAEE) April 1965
THE ERRORS OF AN AIRBORNE DOPPLER NAVIGATION SYSTEM

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE, (Miami); working paper WP-81.

Presented by T. G. Thorne of the Royal Radar Establishment, and Wing Commander J. D. Ackerman, of the (U.K.) Aeroplane and Armament Experimental Establishment, Boscombe Down.

R. Towns September 1964
AN ANALYSIS OF NON-JET TRAFFIC CROSSING THE NORTH ATLANTIC ON 7th AND 8th SEPTEMBER 1962.

Royal Aircraft Establishment, Farnsborough, England; RAE Technical Report 64002.

K. H. Treweek, P. G. Reich, and V. W. Attwooll (RAE) April 1965
THE ANALYTICAL APPROACH TO SAFETY AND ECONOMIC FACTORS WHICH DETERMINE NAVIGATIONAL REQUIREMENTS IN A LONG-RANGE TRAFFIC AREA

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE (Miami); working paper WP-77.

The cost of investment in navigational facilities is compared with the penalties imposed by traffic control to minimize collision risks. Conditions over the North Atlantic in the near future are taken as an example. The danger of assuming a gaussian distribution for the infrequent large errors in navigation (when defining separation standards) is emphasized.

This paper is an addendum to the Reich paper "The RAE Studies of Separation Standards and Collision Risk" (IATA 16, April 1965). Paragraph and figure numbers run serially from the main paper, which also contains the list of references.

K. H. Treweek (RAE) July 1965
AN APPROACH TO THE PROBLEM OF ESTIMATING SAFE SEPARATION STANDARDS FOR AIR TRAFFIC

Journal of the Institute of Navigation (U.K.) London, England; Vol. 18, No. 3.

Restrictions imposed by air traffic control become more significant to operating economy as air traffic increases. The immediate cure is to reduce separation standards. However, this cannot be done safely without understanding the factors and principles which underlie collision risk. This paper deals with the problem of determining safe separation standards with the aid of statistical inference from a sample of observed flying errors.

TRW Systems Group June 1969
NAVIGATION/TRAFFIC CONTROL SATELLITE MISSION STUDY: VOLS. I, II, III

TRW Systems Group, Redondo Beach, California, for National Aeronautics and Space Administration, Electronics Research Center (NASA-ERC), as NASA Contractor's Report (NASA-CR-86166).

An analysis performed for NASA-ERC relating operational requirements in the North Atlantic post-1975 system to proposed technology for satellite usage, aircraft position determination, and communications. In three volumes: Volume I: Summary, by J. H. Craigie, et al.; Volume II: System Analyses (includes the requirements), by Craigie, Dobieski, Raymond, Schultz, et al.; and Volume III: System Concepts, by Craigie, Caprioglio, Renn, Drucker, Pierce, et al.

The resultant hypothesized system is discussed in detail. Each volume includes a list of relevant references.

TSC (DOT Transportation Systems Center) January 1975
ADVANCED AIR TRAFFIC MANAGEMENT SYSTEM STUDY: EXECUTIVE SUMMARY

Transportation Systems Center, Department of Transportation, Cambridge, Mass.; Technical Report DOT-TSC-OST-75-1.

Discusses Air Traffic Control, Surveillance, Automation, Satellites, Upgraded 3rd Generation ATC System. See also "Technical Summary" (March 1975), and "Overview" (June 1975).

J. S. Tyler, D. E. Stepner, and J. A. Sorensen (SCI) June 1972
AN AIR TRAFFIC CONTROL/SURVEILLANCE MODELLING APPROACH FOR SPECIFYING LANE SEPARATION STANDARDS

Systems Control, Inc., Palo Alto, California; Report No. DOT-TSC-260-2 for Transportation Systems Center, Cambridge, Mass. Also published by NATO Advisory Group for Aeronautical Research and Development (Neuilly-sur-Seine, France), in AGARD-CP-105 (June 1972).

Considers relating lane separations to separation (collision risk) for various navigation systems, surveillance systems, and ATC procedures. Describes a model which has two significant extensions to the "well-known Reich model... for specifying North Atlantic route separations." The time-varying nature of aircraft position errors is modelled, and the capability of including an independent surveillance system is modelled. Presents numerical results to show the impact of INS (Inertial Navigation System) and satellite surveillance to reductions of lateral separations of North Atlantic routes to 45 nautical miles (supported by INS only), or to a possible "less than 30 nautical mile lateral separation" with support of INS together with independent satellite surveillance. Use of this modelling technique to determine sensitivity of system parameters is illustrated. See also Technical Report FAA-RD-73-8, "Oceanic ATC Surveillance Systems Study." by Systems Control, Inc., (Stepner, et al.), February 1973, for related work by (effectively) the same team.

J. S. Tyler, Jr., D. M. Brandewie, W. Heine, and R. Adams Summer 1975
AREA NAVIGATION SYSTEMS: PRESENT PERFORMANCE AND FUTURE REQUIREMENTS

NAVIGATION: Journal of the Institute of Navigation (U.S.), Washington, D.C.; Volume 22, No. 2.

Paper presented at the 30th Annual Meeting of the Institute of Navigation, San Diego, California, June 27, 1974. Describes preliminary results of an effort to provide substantiating data for the recommendations of the FAA/Industry Task Force on RNAV (Area Navigation). Tyler and Heine are with Systems Control, Inc. (Palo Alto, California), Brandewie is with FAA (Washington, D.C.), and Adams is with Champlain Technology, Inc. Despite the promising title, this report has little relevency to separation standards studies.

U.K. Guild of Air Pilots and Air Navigators April 1965
BASIC REQUIREMENTS OF THE NAVIGATION SYSTEM

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE (Miami); working paper WP-101.

U.K. National Air Traffic Control Services April 1965
STAFF TARGET FOR IMPROVED NAVIGATIONAL ABILITY

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE (Miami); working paper WP-74.

The longer expression of the title is "Staff Target for Improved Navigational Ability on the North Atlantic Routes--with Worldwide Development Potential." That indicates fairly well the nature and scope of the text.

The U.K. National ATC Services also submitted working papers to IATA Sixteenth including WP-78, "The ATC Requirement for Navigational Capability Over the North Atlantic;" WP-84, "The Requirement for Standardized Navigation Techniques;" WP-87, "An ATC Survey of North Atlantic Navigation Problems;" and WP-102, "The DECTRA System as a Long-Distance Navigation Aid for the North Atlantic."

In these papers, separation standard theory or development is not treated in depth, cost penalty from ATC restriction is considered briefly, and the burden of textual content concerns navigational equipment (airborne and aground) and procedures from the viewpoint of the controller (more) as well as the pilot (less). Stress is placed on the importance of navigational deviation or conformance to safety.

U.K. National Air Traffic Control Services April 1965
THE ATC REQUIREMENT FOR NAVIGATIONAL CAPABILITY OVER THE NORTH ATLANTIC

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE (Miami); working paper WP-78.

The operators and the ATC authority must determine the mutually acceptable balance between the cost of diversions from the most economical track-profile and the provision of more expensive equipment. As traffic tends to concentrate on specific flight paths, accomodation to acceptance of random-track becomes unworkable. The dilemma of navigational capability requirements is avoided; the ATC requirement for navigational capability over the North Atlantic is developed on the basis of the assumption that organized track systems (not receptive to random flight paths) will prevail.

The U.K. National Air Traffic Control Services also submitted the following other working papers to IATA Sixteenth: WP-74, "Staff Target for Improved

Navigational Ability...;" WP-84, "The Requirement for Standardized Navigation Techniques;" WP-87, "An ATC Survey of North Atlantic Navigation Problems;" and WP-102, "The DECTRA System..."

U.K. National Air Traffic Control Services April 1965
THE REQUIREMENT FOR STANDARDIZED NAVIGATION TECHNIQUES

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE (Miami); working paper WP-84.

It is suggested that navigation equipment and techniques might be such as to provide a certain agreed-on capability, albeit recognizing that it would be impracticable to require the use of identical equipment in aircraft on North Atlantic routes. Some reduction in separation standards should become possible were the outlined procedures to be put to maximum use. A larger reduction in separation standards would require systems capable of very accurate fixing of aircraft position.

The U.K. National ATC Services also submitted to IATA Sixteenth the following other working papers: WP-74, "Staff Target for Improved Navigational Ability;" WP-78, "The ATC Requirement for Navigational Capability Over the North Atlantic;" WP-87, "An ATC Survey of North Atlantic Navigation Problems;" and WP-102, "The DECTRA System as a Long-Distance Navigation Aid."

U.K. National Air Traffic Control Services April 1965
AN ATC SURVEY OF NORTH ATLANTIC NAVIGATION PROBLEMS

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE (Miami); working paper WP-87.

The acceptable collision risk for the North Atlantic is assessed, in the light of the method (developed in the U.K.) for determining collision risk implicit in horizontal and vertical separation standards. An accident rate of one in ten million is adopted. It is concluded that no immediate change in separation standards can safely be made, but that the standard of navigational performance should be improved to allow a 90 nautical mile standard of lateral separation between parallel routes. Reduction of the vertical separation standard (presently 2000 feet) to a 1000-foot to 15000-foot vertical separation standard may become acceptable with the provision of sufficient additional data to establish its safeness. Modification of longitudinal separation standards would require further study.

This paper also considers causes of air traffic congestion over the North Atlantic, adequacy of navigational aids to meet present and future demands for accuracy, and increased system acceptance capacity which would result from modifications in separation standards. Appendixes deal with estimation of collision risks in relation to separation standards.

Also published (possibly modified) in Journal of the Institute (U.K.), Volume 18, Number 4, October 1965; and in NAVIGATION, Vol. 10, No. 4, August 1965.

Other working papers submitted to IATA Sixteenth by U.K. National Air Traffic Control Services include WP-74, "Staff Target for Improved Navigational Ability on the North Atlantic Routes;" WP-78, "The ATC Requirement for Navigational Capability Over the North Atlantic;" WP-84, "The Requirement for Standardized Navigation Techniques;" and WP-102, "The DECTRA System as a Long-Distance Navigation Aid."

U.K. National Air Traffic Control Services April 1965
THE DECTRA SYSTEM AS A LONG DISTANCE NAVIGATION AID FOR THE NORTH ATLANTIC

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE (Miami); working paper WP-102.

The U.K. National ATC Services also presented the following working papers at IATA Sixteenth: WP-74, "Staff Target for Improved Navigational Ability on the North Atlantic Routes -- With Worldwide Development Potential;" WP-78, "The ATC Requirement for Navigational Capability Over the North Atlantic;" WP-84, "The Requirement for Standardized Navigation Techniques;" and WP-87, "An ATC Survey of North Atlantic Navigation Problems."

United Air Lines April 1965
AN ASSESSMENT OF NAVIGATIONAL PRINCIPLES AND OPERATIONAL OBJECTIVES

International Air Transport Association, Montreal, Canada; in AIRCRAFT NAVIGATION: Proceedings of the 16th IATA TECHNICAL CONFERENCE (Miami); working paper WP-90.

The viewpoints of one of the prime operators in the Central East Pacific oceanic air traffic control area on topics indicated in the title should be of interest. UAL flights between California and Hawaii carry a full-time navigator and follow flight plans which are computer generated and based on operational and meteorological considerations. The absence of Loran coverage in mid-ocean makes celestial fixes necessary. It is considered that a pilot-operated navigation system would probably be based on an inertial reference rather than a magnetic one. This paper discusses the facilities and displays that would be required.

U.S. Congress August 1971
AIRCRAFT COLLISION AVOIDANCE SYSTEMS

Hearing transcript of the Committee on Government Operations, Ninety-second Congress, First Session, GPO.

J. Villiers 1968
ATC OVER THE NORTH ATLANTIC IN RELATION TO NAVIGATIONAL ACCURACY AND TELECOMMUNICATIONS CAPABILITY

NAVIGATION: Journal of the Institute of Navigation (U.S.), Washington, D.C.; Vol. 15, No. 4. An extract also appeared in ASTRA-1, working paper No. 8.

J. Villiers and J. deBarbeyrac October 1968
AIR TRAFFIC CONTROL PROCEDURES IN A PARALLEL TRACK SYSTEM

Journal of the Institute of Navigation (U.K.), London, England; Vol. 21, No. 4.

Discusses application of a monitoring system using satellites, control of lateral separation, the relationship of navigational accuracy to the problems, control of longitudinal separation with and without monitoring, and the nature of air traffic control intervention, and its frequency and effects. It is concluded that a mathematical model could be used to establish the relationship between aircraft navigational performance (and its monitoring system) and ATC performance (and ATC separation standards). Also considers reduction in separation standards possible with a satellite monitoring system, and reduction in voice communication for ATC.

J. Villiers, J. deBarbeyrac, and H. G. Baudry July 1969
PROJECT "DIOSCURES:" LATERAL SEPARATIONS FOR AIRCRAFT EQUIPPED WITH INERTIAL NAVIGATION SYSTEMS

C.N.E.S. and S.G.A.C., Paris, France.

Project Dioscures was obviously an effort of some weight in the international investigation of the use of satellites in future air traffic control systems. During our bibliographical search, it occurred as published in French or in English in either December 1968, July 1969, or Summer 1969. The subtitle appeared as above, or as "Satellite Systems of Telecommunications, Air Traffic Control, and Navigation."

The magazine "ICARE" issue of Summer 1969 includes (in French), a paper entitled "Future Means of Navigation by Stationary Satellites, and the Dioscures Project" (author missing). This version considers the problems arising from an increase in the number of aircraft simultaneously in flight over the North Atlantic. The most probable procedural response in air traffic control is a reduction in separation standards. Use of geostationary satellites will make possible more accurate fixing of aircraft position. Both the pilot and the controller will act to reduce navigational deviation; and reduced spearation will become acceptable. The use of two satellites for aircraft position fixing, as in Dioscures, appreciably limits the area of uncertainty in aircraft position data input to air traffic control. Villiers and deBarbeyrac also authored "Air Traffic Control Procedures in a Parallel Track System," published October 1968 in the Journal of the Institute of Navigation (U.K.), Volume 21, No. 4.

T. A. Waldeck and R. B. McMurdo October 1967
A SYSTEM SAFETY MATHEMATICAL MODEL FOR COMMERCIAL JET AIRPLANES

AIAA Paper No. 67-910; American Institute of Aeronautics and Astronautics, Philadelphia, Pa.

R. H. Waldman October 1969
COMMERCIAL NAVIGATION SYSTEMS FOR LONG-RANGE SUBSONIC TRANSPORTS IN THE 1970's

Journal of the Institute of Navigation (U.K.), London, England; Volume 22, No. 4.

K. Watling and R. C. Rawlings (RAE/Bedford-UK) February 1976
STUDIES OF AUTOMATIC NAVIGATION SYSTEMS TO IMPROVE UTILIZATION OF CONTROLLED AIRSPACE

NATO Advisory Group for Aerospace Research and Development, Neuilly-sur-Seine, France; AGARD document number AGARD-CP-188, Conference Proceedings of the 20th Symposium of the AGARD Guidance and Control Panel, Cambridge, Mass., May 20-23, 1975.

Looking toward future progress in navigation, separation, and operational planning, identifies practical problems, including workload of pilot or controller. Suggests evolutionary development of the ATC system during the 20-year "period of transition to the future system." Describes possible objectives of the R&D programme leading to that "future system."

Calculates relationships between separation standards and lateral performance (of aircraft track-keeping). Presents a typical breakdown of relative errors from guidance, flight control, and environment. Five pages; ten graphics.

Germane to "separation studies"--although its title would suggest not.

A. White (National Air Traffic Control Services - U.K.) October 1971
AIR TRAFFIC CONTROL SEPARATION MINIMA AND NAVIGATIONAL CAPABILITY

Journal of the Institute of Navigation (U.K.), London, England; Vol. 24, No. 4, pp. 443-456.

First of a series of three articles in this issue entitiled "Air Traffic Control Separation Standards and Navigation." Straightforward and business-like discussion of safe separation standards (and not spacing criteria), which generally reviews the work of the NAT/SPG and the RGCS Panel of ICAO. Treats in sequence main components of the task, navigation errors, ATC intervention capability, and airspace requirements for error correction on airways. Includes several worthwhile graphics and tables (no bibliography).

Herbert Winter (Bell Aerospace Co.) Winter 1971-1972
OPTIMAL AND SUBOPTIMAL METHODS OF SATELLITE SURVEILLANCE FOR TRAFFIC CONTROL OF TRANSOCEANIC FLIGHTS

NAVIGATION: Journal of the Institute of Navigation (U.S.), Washington, D.C.; Vol. 18, No. 4.

Ian G. Wolf April 1971
BEACON RADAR SEPARATION MINIMA FOR JACKSONVILLE ARTC UTILIZING DIGITIZED RADAR

Federal Aviation Administration, Air Traffic Service, AAT-330, Enroute Procedures Branch, 800 Independence Avenue, Washington, D.C.

Unpublished staff study. At the time of its issuance, separation standards specific for digitized radar use had not been published. Currently, the proper reference for such is the Air Traffic Control procedural manual Handbook 7110.65 "Air Traffic Control" and related radar procedure manual materials. However the Wolf document is worthy of consideration by system design specialists who may be confronted with the same challenge; i.e., to implement publishable procedures for an ATC separation standard, given (specified conditions)...

W. Wolff March 1969
AN ANALYTICAL APPROACH TO A SEPARATION HAZARD PREDICTION AND RESOLUTION MODEL

Communications and Systems, Inc.